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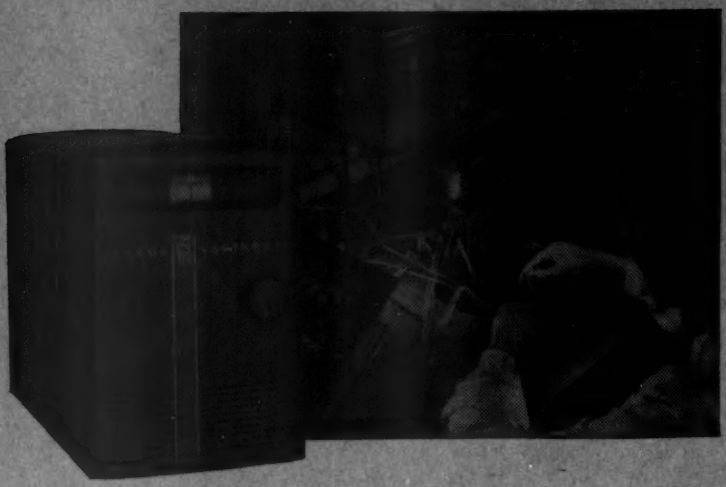

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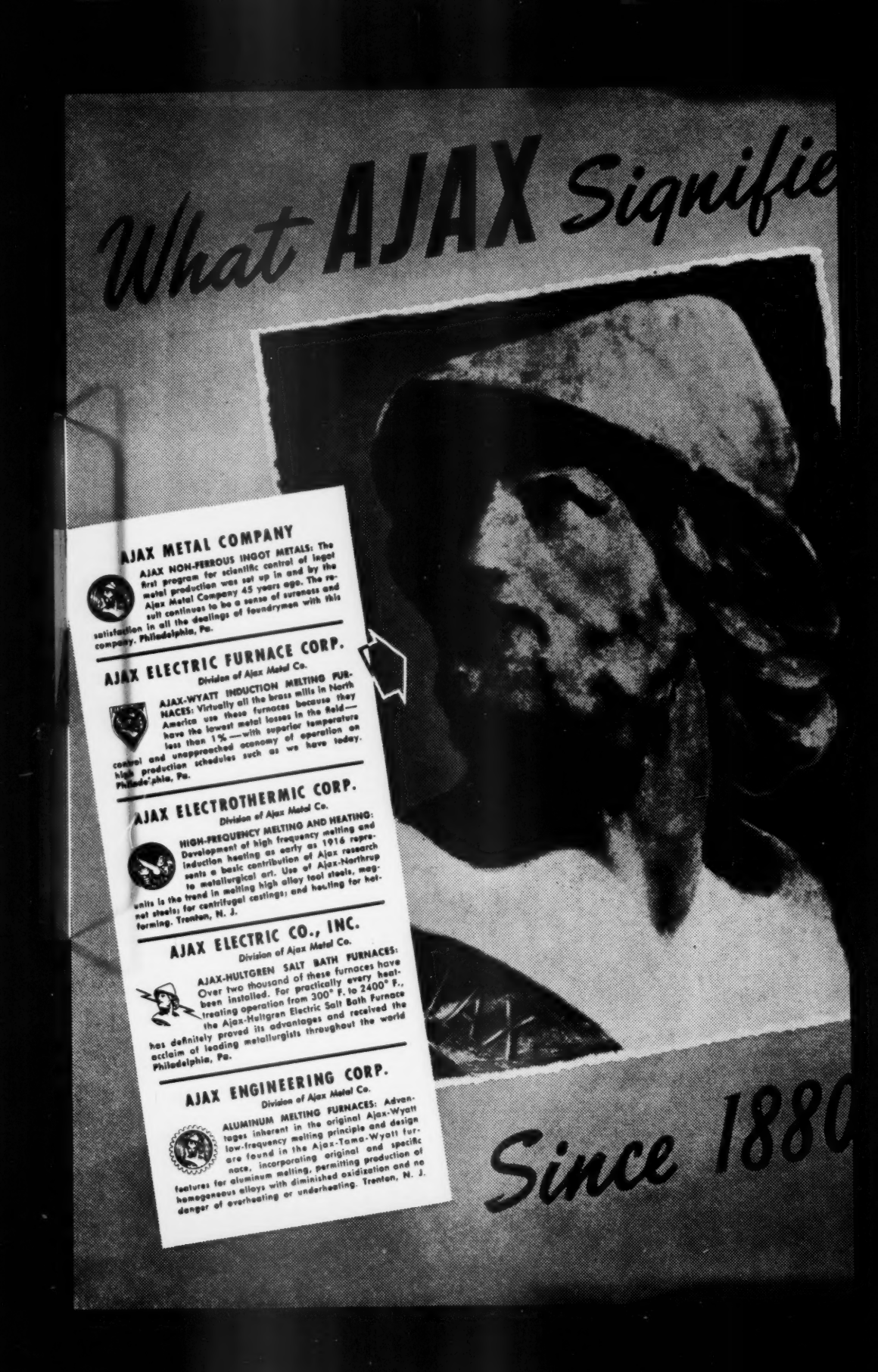
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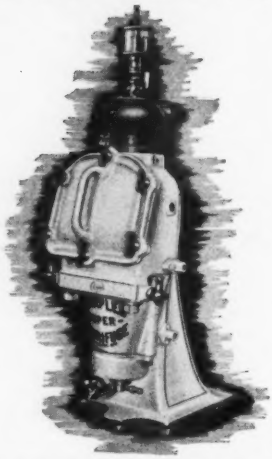

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Journal
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The Franklin Institute
Devoted to Science and the Mechanic Arts

Vol. 247 MAY, 1949 No. 5

THE LIFE AND WORK OF EDWARD GOWEN BUDD.[1]

BY

G. L. KELLEY, Ph.D.,[2]

Two principal themes would seem to be simultaneously appropriate to the present occasion: one is to pay a tribute to the memory of a man held by all in the greatest respect for his human qualities; the other is to claim for the story of his work the place in industrial history that it deserves.

When Edward Gowen Budd died here two years ago, on November 30, 1946, he was within a month of celebrating his seventy-sixth birthday: he had come to Philadelphia at the age of 18 from Smyrna in Delaware, where he was born on December 28, 1870. As it is nearly forty years since he first discussed the project that led to his success, no one who is now much less than 60 years of age could speak from first-hand knowledge of the background against which alone both the man and his work can appear in true perspective.

Mr. Budd's claim to public remembrance, however, does not rest solely on the physical fact of a pioneer development: it is because of what he was as a man, no less than what he did as an industrialist, that he is worthy of this commemoration: and the human aspect that calls for emphasis was his ability to inspire the team in which he himself was one of the hardest workers. This influence was not limited to those fields in which he knew the job personally; to borrow a word from chemical science, his effect in an organization often was mainly catalytic; outside of his own field he engendered and fostered to success a number of important developments, of the commercial need for which he had

[1] Presented under the Edward G. Budd Lecture Foundation of The Franklin Institute of the State of Pennsylvania; given in the Hall of The Franklin Institute at the Stated Meeting held February 16, 1949.

[2] Deputy Chairman, Pressed Steel Co., Ltd., Oxford, England.

(Note—The Franklin Institute is not responsible for the statements and opinions advanced by contributors in the JOURNAL.)

an acute perception. In life he acknowledged promptly and generously the help that he received from others in such enterprises.

During nearly all of his business life he lived in Philadelphia, directing the operation of Works there and in Detroit. The purpose of this lecture is to describe parts of his life and work. Constantly, throughout an unusually long productive period, he was a many sided industrial pioneer. He not only started new industries, but through his foresight and energy, he fostered and furthered the development of many ancillary industries. It is because it is so easy to trace the origins of the large scale development of these industries to his influence, that a recapitulation of his accomplishments is so worthy of record. It is also a reason for the difficulty encountered in giving a representative outline of his work within a reasonable space. Too many of his actions and interests seem to merit mention.

His early paternal ancestors were English colonists who settled in New Jersey in 1688. William Penn had arrived only five or six years earlier. Apparently, his immediate forebears moved to Philadelphia late in the eighteenth century. Among them was the man who built the so-called Budd Row, the first of the row houses so typical of Philadelphia. His grandfather, a man in comfortable circumstances, lived in Philadelphia. His father, during his youth, did not enjoy good health and, after trying life in other places, finally left Philadelphia and settled down in Smyrna, Delaware, where he served as a Justice of the Peace. His mother was Caroline Cattel, daughter of a New England clergyman. They lived in Smyrna for about thirty years, where five children were born, of whom Edward was next to the youngest.

He attended public school in Smyrna and graduated from the local high school. During the period in which he attended high school, he spent most of his summer vacations on the farm of an uncle, Mr. George Biddle, in Cecil County, Maryland. As a youth, he was very fond of baseball and played it well. He was the first in his town to own a bicycle.

After graduating from high school he started an apprenticeship in a small machine shop in Smyrna run by Elmer Taylor. About 1888, at the age of 18, he went to Philadelphia to seek employment. Apparently he worked for some time for William Sellers & Co. About 1890 or before, he undertook apprentice training as a machinist with Bement, Miles & Co., the early predecessors of the Niles, Bement, Pond Company. He was ultimately made drafting office foreman of their hydraulic press design group. Leaving them about 1896 he was employed at the Jacob Nayler Machine Works, and perhaps other places. Keenly interested in education, early in the 90's he added to what he had by taking a four term course in Mechanic Arts at The Franklin Institute. He desired to master the mathematics necessary to the understanding of gear design, and while with Bement took courses

in this subject in the International Correspondence School. Still later he took an electrical course from this school. As he grew older he gradually came to cultivate broader fields of learning; he could always find interest and escape from the petty things of life by turning to his favorite authors in history, biography and poetry. He was particularly interested in the lives of great men of the past.

In May, 1899, he married Mary Louisa Wright of Philadelphia, the daughter of Archibald Wright, a descendant of Scotch-Irish immigrants, who had been a surgeon with the Union forces during the Civil War. His wife and their five children, three daughters and two sons, are still living. At the time of their marriage, he and his wife joined the First Methodist Church of Germantown, in which he remained an active member until his death. He was interested in the affairs of his community and in politics but this did not lead to active participation. He was a regular contributor to a large number of religious, charitable and social service organizations.

His membership in scientific, technical and engineering societies included many national and local institutions. On May 13, 1932, he was awarded the John Scott medal for work on stainless steel as a structural material, and in 1943, he was awarded the Good Citizenship Medal of the National Society of the Sons of the American Revolution. The 1944 American Society of Mechanical Engineers' Medal, in the citation, gave him credit for pioneering the manufacture of welded all-steel automobile bodies, the steel disk wheel, the SHOTWELD[3] process for welding stainless steel and for the practical use of stainless steel in such structures as railroad passenger train cars, bus and truck bodies, and airplanes.

He was a member of many social clubs in New York City, Philadelphia, Detroit and Washington; but above all, he was a family man and spent as much time as he could in his modest home in Germantown where he and his wife enjoyed their children and later, their grandchildren.

After his marriage, his first employment was with the American Pulley Company in Philadelphia, which had been established during April of the same year. It was here that he had his first experience with sheet metal press work. His next occupation, beginning in 1902, was with the Hale & Kilburn Manufacturing Co., also of Philadelphia. During his stay with Hale & Kilburn he found opportunity to develop further manufacturing processes involving sheet metal press work and to improve gas and various types of electric welding. It was these processes which were to become so important when later he established his own business. It was also while he was with Hale & Kilburn, probably about 1909, that he undertook for Mr. Emil Nelson, then Chief Engineer of the Hupp Motor Car Company, the manufacture of

[3] Trade mark registered.

pressed steel panels for use in making all steel automobile bodies. He had become General Manager of Hale & Kilburn, but, beginning in 1910, the policies of that Company proved so unacceptable that he later resigned. During several years he had used half of his $5000 salary to purchase shares in Hale & Kilburn. On his resignation, the $70,000 paid to him for his shares was the basis of his financial interest in his own business, which he established in July, 1912.

He rented his first shop at Aramingo and Tioga Streets in Philadelphia. Because of its small size, his only large press was installed in a rented canvas circus tent, pitched on an adjoining lot. At this time he was 42 years of age and he had already gained a reputation as a genius in forming metal sheets. His entire original labor force was twelve men, of whom eight are still with the Company, four having died. Among these, special mention should be made of three men: Mr. Joseph Ledwinka, a man of unusual inventive ability, who was his Chief Engineer; Mr. Joseph W. Meadowcroft, who directed welding developments with tireless energy; and Mr. Leo Heintz, now several years deceased, who was Mr. Budd's first Works Manager, a genial and able operating man. These men, with Mr. Budd, formed the nucleus of the new company on the technical and production side.

The inadequate factory space prompted a move to larger and better quarters and the limitations imposed by his small capital were removed by, and with, the assistance of his good friends and associates, Mr. H. L. Adams, Mr. W. B. Read, Mr. A. Robinson McIlvaine, Mr. Joseph Steinmetz, Mr. J. B. Burdette, Mr. Alan Wood III, and other members of the Wood family. This growth, begun so early in the history of this small Company, became a characteristic of the enterprises with which he was associated throughout the remaining thirty odd years of his business life.

Edward Budd was a man of many ideas. His energy, engineering talent, and inventiveness were greatly admired. The prescience in deciding upon those articles which his Company could make and for which there would be a large public demand was then not yet recognized. His own almost unlimited faith in his ideas was not always shared by his associates, who, with him, had the responsibility for the financial health of the Company. Despite the restraining action of his more conservative colleagues, there were many times when difficulty and danger threatened. It was at such times that his unfailing courage kept hope alive until the crisis had passed.

The Company first made steel truck bodies and the step from this to automobile bodies was a natural one. Mr. Charles R. Nash, then President of General Motors, was the first substantial customer. By 1914, John and Horace Dodge, former engine builders, began to manufacture their own cars. They became the Company's first large quantity buyers. Not long after, the United States entered the first

World War. While this led to the immediate suspension of its normal business, Dodge touring cars were supplied as standard equipment for the Army.

Throughout his life, except during his later years, Mr. Budd's health was good. He was tall and of the vigorous, energetic type. He expected great effort from all of his associates but not more than he put forth himself. When an emergency required it, he could be found at his desk early or late, weekday or Sunday. His was a nature which required that a task once undertaken should be pursued continuously until it was completed. He was impatient of reasons which prevented the early completion of tasks and resourceful in suggesting methods for overcoming the delay. Any piece of work to be done satisfactorily must be done both quickly and well. Any difficulty which was put forward as a reason for preventing the attainment of some desired object, he could show was only an obstacle to be overcome. He is said to have confided to an associate "I make it a practice to ask the impossible of one of my people daily, and quite often they do it." This general attitude he successfully communicated to his organization until it operated in large degree in every department.

While he wanted everything done quickly, he was also interested in achieving the utmost in quality consistent with a reasonable cost. He frequently took the position that it costs no more to make a good article than a poor one. Here he had in mind not only quality as determined by appearance but also sound engineering and structural values.

In the interest of low cost production, he expected his employees to put forth a creditable productive effort. At the same time, he maintained that a good foreman did not drive his men. Instead, such a foreman found methods which made increased production easier. In the shop, his experienced eye quickly detected any unnecessary element in a series of operations, particularly if its presence caused the workman to waste his strength or energy. His manner with workmen was easy and friendly but not familiar. He was not of the "back-slapping" type. He was always ready to listen with a truly open mind to complaints or suggestions from workmen. All his life he favored a good wage for a good day's work. His labor policies were up to or in advance of his times and he particularly believed in those good relations which flourish best in an atmosphere in which there is mutual understanding and respect between management and men.

He organized efficient plant safety engineering sections in which he took an active interest. Metal working plants as a whole usually have a relatively high accident frequency rate. In 1946 this was 29.1 per million man hours worked, and the figure for industries in their entirety was 19.9. The corresponding Budd figure in both 1946 and 1947 was 10.6 per million man hours, and in 1948 it was 8.9.

Each new Budd employee receives a Company-paid insurance policy

in the amount of $250.00, increasing automatically to $1000 after a year. In the case of death, the Company continues to pay the worker's salary for three weeks. The Employees' Compensation Act requires a $20. weekly payment to employees who are unable to work because of injury. The Company pays its employees an additional $20. per week. To deal with illness or injury not connected with his job, two units of sick and accident insurance paying $20. per week are issued to each employee. Two additional units, providing a total of $40. per week are available on the payment of a small fee. Other forms of insurance are available, covering the workman's entire family, for hospital expenses, surgeon's fees and other costs resulting from sickness or injury, all on the payment of a small amount.

Having in mind the physical well-being of Company employees, restaurants and lunch booths, conveniently located, provide good food at moderate cost to workmen on all shifts. Another beneficial arrangement in the plants is the Employee Exchange. This Exchange was established to help out needy employees by loans or through the purchase of food and coal to be given to families in distress. The Exchange sells candy, cigars, cigarettes, work-gloves, safety-shoes and other small items. Some articles are sold almost at cost, but any profit made is used to take care of charitable work. Some employees who are no longer able to stand the physical strain of shop work are given employment with the Exchange.

In the field of industrial medicine, he was again a pioneer. Since its establishment in 1915, the Medical department has become a very important part of the organization. It is particularly notable that it occupies a position of power and influence. Clinics, equipped with the most up-to-date medical apparatus are maintained at all plants, and emergency first-aid stations are placed in strategic locations. Complete operating rooms, elaborate X-ray apparatus, a well-equipped laboratory and facilities for physiotherapy, make the medical service to Budd employees one of the best in the whole country. There are now nine doctors and thirty-four nurses on duty in the various clinics. In addition, there are visiting nurses available to call on sick and injured employees at their homes.

Mr. Budd felt strongly that there was an identity of interest between the Company and its employees. It is impossible within the space of this lecture to discuss these matters adequately, but at least mention should be made of arrangements for the gainful occupation of handicapped persons, the provision of a Building and Loan Association for the convenience of its employees and a training scheme which provides a wide range of training for apprentices, foremen and even University graduates. A foremen's institute aims to train general foremen in the organization of conferences with their assistants on production problems. Junior and Senior Seminars discuss a wide

variety of topics of their own choosing under strict parliamentary procedure.

Budd's business grew rapidly from the start. During all of his early years, he had often to decide whether he would be justified in accepting a new order if in doing so he committed his Company to a large capital expenditure. Time has shown that he was successful in tempering with the right amount of caution, an exceedingly adventurous spirit. If at times the whole structure appeared to be threatened, fortunately these threats presently disappeared and the affairs of the Company entered upon a happier phase.

In general, he held the view that an assured market existed only for those manuracturers who produced a good article at a low price. With the object of meeting these conditions, any reduction in costs was passed on to the customer in reduced prices. If buildings, equipment or materials were needed, the steps necessary for their provision had his support. His efforts to achieve success led, in many instances, to developments of lasting benefit to industry. An effort will be made in the course of this lecture to describe some of the more important ones.

The first item in a fairly extensive list was the all-steel automobile body. The experience of the last few months with Hale & Kilburn in manufacturing Hupp Motor Car bodies entirely of steel appears to have suggested to him the advisability of adopting for general use the all-steel all-welded type of body construction. He gave up an important and lucrative position to establish a company of his own, and its principal objective became the manufacture of all-steel automobile bodies. In doing so, he became the pioneer in the quantity production of automobile bodies by this method.

At the time Mr. Budd chose to launch his company, the annual production of automobiles in the country was 350,000. This is trifling compared with the current production of over 5,000,000. Then some of the automobile companies made their own bodies but many were bought from relatively small companies. The materials ordinarily used included wood for framing purposes, covered usually with sheet steel, leather or canvas. Bodies were almost exclusively of the open type called "touring." Where sheet steel was used, the panels were shaped on small presses of various types. To this situation he had brought the new idea that bodies should be made entirely of sheet metal stampings assembled by welding. In trimming, the upholstery methods and materials employed at first were those in use by the carriage industry. Early design naturally followed the trends already established. Painting, too, made use of many coats of varnish, each undergoing a long period of air drying. The whole system was expensive and unsatisfactory.

When, however, we consider the poor quality of sheet steel then available and the few known arts for shaping and assembling it into

bodies, we can see how much urgent developmental work lay ahead of this young organization.

The sheet steel available suffered from defects of surface, gauge and ductility. The generous cooperation of the steel mills contributed to the gradual and steady improvement of the material. Budd engineers produced a type of roller leveller which usefully removed stretcher strains, an extremely troublesome surface defect. They also developed a sheet welding machine which joined together two narrow strips or sheets to make a wider sheet of better quality than could be obtained in such widths from existing hand mills.

The demand for a large and cheap production of sheet steel stampings brought many new problems to light. The need for making deep draws in which there was seldom symmetry pointed to the use of double action dies and presses and to the need for improvement in their design. His conception of the all steel body gave to press design and manufacture an impulse which is still felt. To-day, the automobile industry leads all others in the use of electro-mechanical and electro-hydraulic presses for the manufacture of sheet metal products.

At the time Mr. Budd began to use welding procedures in connection with his plans for assembling steel bodies, gas welding was already somewhat developed but there were needed better methods for making oxygen and acetylene and better valves, tanks and torches for handling the gases. Arc welding was not yet suitable for welding thin steel sheets. Electric spot welding was the method most useful to him for joining metal panels and Budd joined with the manufacturers of this equipment in extensive programs for its improvement. The Company became at the time, and remained for many years after, the world's largest user of this type of welding.

Body design had for its object the production of bodies of agreeable appearance which were also functionally satisfactory. The all-steel body required that the very large number of separate steel parts should be capable of easy and exact assembly without hand fitting. The lack of symmetry and the varying contours made necessary the provision of a special drawing technique in body design. The development of this was gradual and it had for its basis the full size completely detailed lay-out. This system for body drawing, gradually spread through the industry until it is at present in use throughout the world.

The early bodies were for touring cars. Since in his design he avoided the use of wood, it became possible to use painting procedures which involved baking at temperatures not possible otherwise. This was in fact one of the outstanding advantages which he claimed for the all-steel body. To this end black japan was applied to panels and panel assemblies which, after cleaning, had been previously heated to a temperature of 500° to 600° F. to remove the last trace of oil. Under the best conditions, a black coat of excellent appearance and remarkable

durability resulted. About 1920, or perhaps earlier, in the case of most companies, automobile bodies were painted with nitrocellulose lacquers, at first experimentally and then in production. Mr. Budd regretted that the nitrocellulose lacquers were less durable than the black enamels which they replaced. This caused him to start experiments leading to the production of a type of paint, which, if completed, would have closely resembled the current synthetic enamels.

It will be recalled that when he started his Company in 1912, only touring cars were being made other than in custom types in small quantities. World War I, which began shortly after, prevented active development of automobile design. It was partly because of this that sedan bodies were not extensively produced by the industry until 1922. However, as early as 1919 Budd entered the field with a sedan body constructed wholly of steel, and in 1922 commenced large scale production of them while other companies were still using wood. Budd designs, although in the early days made of many pieces, were from the outset stronger and more rigid than the composite type of body. Mr. Budd took an important step towards the reduction of noises within the car by developing sound-deadening preparations for application to critical surfaces. These procedures gave extremely satisfactory results and they continue to be used throughout the world.

Quite early he saw the advantages involved in reducing the number of pieces on the one hand and producing at the same time, as nearly as possible, a design in which the necessary outer skin carried most of the stresses. This line of thought, applied to the sedans, ultimately gave rise to the one-piece side panel and sometimes earlier, sometimes later, to one-piece roof panels, one-piece inside and outside door panels complete with window frames, and one-piece floors. The design at that time of dies and jigs which would produce a one-piece side panel of the required shape and dimensions was a major undertaking. The success thus realized established practices since followed widely throughout the automobile industry. The principle involved saved weight and labor and gave a safer, stronger, more rigid product.

It was at this point that Mr. Budd decided to test his all-steel "monopiece" body against a composite type. A nearby cliff, a specially designed runway at the top and a supply of cars, some with Budd "monopiece" steel bodies and others fitted with composite bodies of other manufacture, provided the material needed for the test. Other adjuncts were moving picture cameras to show the course of the car as it fell over the edge of the cliff to the ground below and, on at least one occasion, a thrill was provided by engaging a well padded movie stunt performer to sit in the car during the fall. The last views in the picture always showed the car with the composite type of body a hopeless wreck while the battered but otherwise undamaged car with the all-steel body was driven from the scene by a smartly uniformed chauffeur.

The genius behind this was certainly not a showman and it could be truthfully said of him that he abhorred ostentation in any form. One can imagine that he accepted the sensationalism which was inevitably a part of such a display with a certain amount of embarrassment. It is difficult, however, to imagine his real feelings when he was persuaded that he must exhibit his steel bodies with a live five-ton elephant standing on the roof of a body.

In 1919 Mr. Budd entered into a contract with the Michelin Company by which he obtained a license to manufacture and sell the tapered steel disk wheel of their design. The disk, which was of uniform thickness for a distance from the center, tapered uniformly to one-third the thickness at the periphery. Mr. Budd and Mr. Ibach designed a die-rolling process by which the disks were at first made, but later they were made much more satisfactorily on a mill designed by Mr. J. W. Smith and modified by Budd engineers. On this mill it was possible to produce, by cold rolling, tapered disk wheel blanks having a good surface and excellent physical properties.

The wheels used on automobiles up to this time were mostly of the artillery type wooden wheels, which were both heavy and expensive, and various patented designs of wire wheels which were light in weight but expensive to make and not too satisfactory in service. By a careful study of the rim section it was possible to reduce the wheel weight by taking full advantage of the strength contributed by the fitted and rivetted joint between disk and rim. In the making of the disk and rim assembly he eventually introduced almost wholly automatic manufacturing features. By these means he succeeded in producing a serviceable steel disk wheel in which he had materially reduced the cost and the weight.

An advantage of the Michelin design was that the wheel, besides being of the demountable type, was so designed at the hub as to provide a self-centering and self-tightening mounting. This feature was utilized in tandem in the manufacture of the dual wheels which came to be widely used.

Out of these developments came the single stamping artillery type steel disk wheel. This wheel became standard and remained so until the advent of large tires and small wheel body diameters again made a place for the plain disk wheel.

The Budd Wheel Company was started in Philadelphia in 1916, but in 1925 it was transferred to Detroit. It has since been absorbed as a part of The Budd Company.

In 1919, at the time of entering into the Michelin disk wheel license arrangement, The Budd Company was doing extremely well with its steel body business. During that year, Mr. Adams went to Europe at the invitation of the French High Command. Before starting on this trip, Mr. Budd and Mr. Adams, using the services of a professional

cinematographer, made up 5000 feet of film showing the manufacture of an all steel body in all of its stages. Mr. Adams, who was the moving spirit in the European development, showed these films to Messrs. Renault and Citroën in Paris and to the Austin, Morris and Standard Companies in England. This, and other European visits later, resulted in license arrangements with M. Citroën in Paris, France, and Mr. W. R. Morris in Oxford, England. A subsequent visit to Germany gave rise to the formation of the Ambi-Budd Company of Berlin, Germany.

The arrangement with the Citroën Company was completed in May, 1924. Budd representatives gave the Citroën Company every kind of service as long as the contract continued in force, a period covering a great many years. It was during this period that Citroën developed his front drive unit and, in collaboration with Budd, evolved the integrated body and chassis unit in light gauge steel construction upon which it was mounted. Budd had previously experimented with this type. This is the first example of a combined body and chassis produced in a standard design in large quantities. Interestingly, the Citroën design is still current.

During 1926 the Ambi-Budd Company was formed. In the automotive field this Company made bodies for most of the leading German automobile manufacturers. Its methods were based on those used in the Budd plant in the U.S.A. The Ambi-Budd Company also developed for use by one of its customers a light-weight steel chassis joined directly to the body by spot welding. This was the second such example of integral body and chassis design. The German Company for several years before World War II carried on a prosperous business.

In 1925, Mr. William Morris, a prominent British automobile manufacturer, located in Oxford, England, resolved to reorganize his business and manufacturing methods in a way to provide for the production of a large number of automobiles at low cost. During a visit to the U.S.A., Mr. Morris (now Lord Nuffield) met and entered into an agreement with Budd which ultimately resulted in the organization of The Pressed Steel Company of Great Britain Ltd., the stock of which was principally controlled by Morris and Budd. Under this, Budd undertook to supply technical information for the manufacture of steel bodies. The works for doing this were established at Cowley, Oxford, in 1926, next door to the Morris Works. The relationship continued until 1930 when, with good will on both sides, Mr. Morris parted with his equity interest in the concern. Mr. Budd retained his Company's interest until 1936 at which time he sold it to another British group. This led to a Company reorganization and the issue of shares to the public. The name became Pressed Steel Company Limited.

Above, mention was made of designs introduced by Citroën and Ambi-Budd which involved a combined body and chassis frame. About

1934, the Pressed Steel Company Limited produced another and original design, combining body and chassis frame, which has had wide use in England and on the continent. The Budd Company has pioneered in America the development of designs involving the self-supporting body.

That the system of all-steel automobile body manufacture devised by Edward Budd should have led to the license arrangements related in connection with Ambi-Budd, Citroën and the Pressed Steel Company in itself offers convincing evidence that it was of prime importance to the industry. License arrangements with leading companies were later established in France, Italy, Germany, Austria, Czechoslovakia, Poland and Sweden, besides those previously mentioned, and much business was done in Russia. In the meantime, the system had been adopted by all American manufacturers of automobile bodies. No contribution other than one of a distinctly fundamental and revolutionary character could have achieved this universal acceptance.

About 1928 to 1929, Mr. Budd began a broad consideration of materials for construction other than steel. He was working with stainless steel at the same time. In this material he did not find light weight *per se* but he did find in its cold worked forms, great strength, a high strength-weight ratio, great ductility and complete resistance to corrosion by exposure to weather. It welded easily but the weld required that the conditions of welding be properly controlled. The method of welding stainless steels which resulted from these studies became known as the Budd SHOTWELD system.

Throughout the remainder of his life he was fascinated by the possibilities of stainless steel as a structural material. In 1930 and 1931 his staff constructed a great variety of airplane and seaplane parts at first experimentally and for demonstration, and then on order, and in 1931 they built an entire amphibian seaplane. This seaplane, the first to be built in stainless steel, was flown 100,000 miles in demonstrations all over Eastern United States and Western Europe and is today on exhibition outside The Franklin Institute.

Later, he caused designs to be developed, and the manufacture undertaken, of various ship parts. Here he could capitalize the high strength of stainless steel for, owing to its resistance to sea water, it was not necessary to provide against rust failure either by painting or by adding large amounts of steel otherwise unnecessary.

While great numbers of airfoils and other airframe parts were supplied on order for test purposes for the U. S. Government and the aircraft industry, Mr. Budd did not find an opportunity to make complete airframes of stainless steel in quantity until World War II. Then the U. S. Navy Department placed with him an order for 1000 cargo planes. The manufacture was tooled for large production, the airplane was built, successfully passing all tests, and it was duly accepted for

production. By the time production had begun in earnest, the service call was changed and production halted.

In the preceding paragraphs, an outline has been given of Budd's application of stainless steel to the manufacture of airplanes and certain ship parts. Interestingly, in 1931 or earlier, the Michelin Company developed in France a light weight rubber-tired car to run on standard rails. The light weight advantages inherent in the use of a non-corrodible stainless steel construction were evident and Budd took a license to build in America rubber tired rail cars.

The Michelin car was shown to him in France in September 1931. By January 1932 he was demonstrating his first experimental rubber-tired stainless steel rail car. This furnishes striking evidence of the speed with which he worked. The first car, called the Green Goose, was equipped with a Junkers 85 hp. diesel motor. The second car, built for Michelin and called the Lafayette, was completed in May, 1932. It was equipped with a 90 hp. gasoline motor of French make. A larger car, capable of carrying 47 passengers, and ordered by the Reading Railroad, was equipped with a Cummings diesel motor of 125 hp. It was completed in October, 1932. The Pennsylvania Railroad next ordered a two-car train with a 125 hp. diesel motor in each car, which was delivered towards the end of 1932. An order from the Texas and Pacific Railroad for a two-car train in which one of the cars was rubber tired, completed the list of rubber-tired cars built by Budd on the Michelin principle.

American car specifications were too severe for the load carrying capacity of tires then available. The result was that the Michelin license was regretfully given up, although the several cars built in America to this design created a great deal of interest.

It will be recalled that during the early 1930's the country was suffering from a severe depression. Millions of workers were unemployed. Mr. Budd felt that diversification in the work of his Company might reduce the risk of unemployment. It is probable that this factor entered largely into his decision to build stainless steel railroad cars. A time came when he decided to give up all other forms of stainless steel manufacture except the quantity production of large truck trailers and railroad cars on steel wheels.

The early efforts on the design of rail cars paid excellent dividends in the coin of experience. The data acquired in the earlier work were immediately useful in the design of the Burlington Zephyr, a three-car articulated train equipped with a 600 hp. diesel electric power unit. This train was so highly successful that the interest of the railroad engineers was thoroughly and permanently aroused. The Burlington Zephyr was a fundamentally new development in the railroad world and it definitely pioneered the current railroad car revolution. The next trains were the Flying Yankee on the Boston & Maine Railroad, the

Twin City Zephyrs on the Burlington, the Burlington's Mark Twain, and the Denver Zephyr. These trains were built in the years 1934, 1935, and 1936. They were capable of running at 100 m.p.h. and their schedules called for 90 m.p.h. Each contained its own power unit and all were articulated.

Carefully examined engineering considerations had led at first to the embodiment of the principle of articulation and the use of an integral power unit in Budd trains. As early as 1936 both of these features were found to have disadvantages. After a relatively short transition period, articulated trains were replaced by trains in which the cars were joined by standard coupling. The first of these independent coaches was built for the Sante Fe Railroad. During 1937, one hundred and four of these new cars were built for the Sante Fe Railroad.

At or near this period Budd ceased to build locomotive cars and to supply the power unit, save in occasional instances. Five of the Budd built trains, the Pioneer Zephyr, the Flying Yankee, the two Twin City Zephyrs and the Mark Twain Zephyr, had identical diesel electric power units designed and supplied by General Motors. All are running satisfactorily to-day. Their locomotive cars, the joint effort of General Motors and Budd, may be regarded as the pioneer prototypes of the diesel electric locomotives which today draw the great stream-liners over the American continent.

Placing his faith in cold rolled stainless steel as a structural material Budd organized a many sided design group, having for its object the design of a car at once stronger and lighter than any other. One would expect that experimental prototype cars would be built and tested. Instead Budd asked that design be for production because he realized that a car or train can be truly tested only when it is put into the revenue service for which it was built. One of the early trains has covered $3\frac{1}{2}$ million miles and is still in service. By this bold stroke, years of expensive development were saved.

In the Budd design of cars, he early adopted railroad standards and exceeded them. The compressive strength of some of his stainless steel cars is more than twice that of the minimum standard, an impressive ratio in a car weighing only little more than half as much as the early standard cars. The body design was so refined that not many engineering structures equal it in the economic use of material.

In a preceding paragraph, it was mentioned that he put his newly designed cars directly into service from the shop. In spite of this, every factor affecting the quality of the design was subjected to rigorous examination and test. No expense was spared to provide testing equipment capable of searching out any fault. Among many pieces of special equipment, probably the most impressive was a machine which

could subject the largest and strongest cars to a compressive load of 2,000,000 lb., a load far in excess of any existing requirement.

The field of accessories is a wide one. He was not content to accept seats and berths of old and well worn designs. New, if not indeed startling, developments in decoration, room design and arrangement were insisted upon, but always he kept in mind that these necessary improvements must not interfere with the attainment of the light weight objective.

The development of the disk brake, elsewhere discussed, may possibly become the most important contribution to railroad brake development since the advent of the air brake. In itself it is a revolutionary contribution to the safety of the railroad.

The work on the Budd light-weight steel cars began in 1931. Even at the time of his death in 1946, it was a comparatively recent development. The evolution of this type of car under his hands will thus be seen to have been extremely rapid. So great are its merits that all other car builders entered the field soon after Budd and are now building their several versions of this type of car.

Stainless steel cars, built to Budd designs, are running in Italy, Portugal and France. Licenses to manufacture have been granted to French and Italian companies. A strong interest has been shown in them by South American and European Railroads, and a large number of cars are now being built for the Central Railroad of Brazil.

He regarded the railroad clasp brake as being as antiquated as the brake used on wagons where the brake shoe bore on the steel rim of the wheel. He pointed out that on railroads the brake not only contributed to wheel wear, but in addition involved the risk of thermal damage to the wheel. The railroad brake, with its metal shoe on a metal wheel, perforce tended to be noisy and jerky in operation. This contrasted unfavorably with the quite and smooth operation of the automobile brake.

His interest took active form in 1937 at which time he authorized work on the Budd disk brake, a railroad braking system involving many wholly new design features. Having had the foresight to recognize the the need for improvement, he proceeded to attack the problem. He realized that unless these fast stainless steel trains could be made to stop at a relatively faster rate, the increased speed would be at the expense of safety. In short, the importance of a high deceleration rate became the focal point of attention when high speed became a factor. The disk brake system, which was developed out of these experiments, has been in regular service for several years on a number of through trains, and yet other railroads have recently ordered it.

Mr. Budd had explored the possibilities of rayon spinning, special forms of high frequency electric induction heating and transparent plastics, the latter as a substitute for clear glass. It is not astonishing,

therefore, that gas turbines and jet propulsion came in for consideration as substitutes for the internal combustion engine. This investigation resulted in the development of certain novel features in the compressor and turbine elements but it was not pursued to a successful outcome.

At the time of World War I, Budd's company, established only a few years earlier, was still relatively small and its financial resources limited. Nevertheless, with characteristic energy and decision, he turned over the entire capacity of the Company to the war effort. In World War II, when the Company was much larger and its facilities proportionately greater, he once more devoted all of his manufacturing capacity to the service of the Government.

When this lecture was planned, it was realized that no single lecturer could cover all of the chief activities of a man having such a variety of interests as Edward Budd. It was therefore decided to emphasize principally the technical developments for which he was responsible. Unfortunately, this has resulted in a much too brief reference to his interest in the commercial and production aspects of his Company. He would be among the first to recognize the importance of these and he would regret deeply the lack of opportunity to recite here the successful outcome of the whole hearted support he received from his associates in these fields. Perhaps an opportunity to remedy this situation will arise in another place.

In reviewing the life work of Edward Gowen Budd there is a difficulty in determining which aspect of it is the most important. Not many would say that his outlook was mainly commercial, but he could not have built up such a large business without giving much of his attention to the commercial side. Manufacture on a large scale involves heavy capital expenditure but when extensive tooling or elaborate technological development promised greater production or lower costs, these production devices received his support. As a result of the policies for which he was responsible, he had the satisfaction of seeing his employees grow in numbers from twelve persons to over twenty thousand.

He was extraordinarily fond of work and there is no doubt that his evident success as an industrialist in producing on a large scale gave him much satisfaction. In addition, he was fascinated by the possibilities of increasing production through invention and technical development. It is customary to say of business men, and especially of those who operate on a large scale, that they work either for financial gain or for love of power. The extremely modest way in which he lived would seem to indicate that his motive was not that of making money for himself and certainly no one who knew him well would feel that he loved and worked for power.

Besides regarding his Company as useful in producing more of the goods which society demands, he felt that it also provided occupation and opportunity for a large number of people. That this thought

influenced him is shown in the many steps he took to provide for the betterment of his employees, both physically and mentally. Industrial welfare, in the broadest sense, is not always wholly disinterested, and it is often utilitarian, but Budd's approach to it went so far beyond these limits that a special humanitarian quality is recognizable.

He was a natural leader of men. If he vigorously urged results, he also took extreme care that wounded feelings did not result. Consistent kindness was an ever present quality of his nature. It was his constant aim to surround himself with men of high character, and exceptional training and ability. To these he delegated authority as rapidly as they were able to exercise it in the general good. His patience with those who were slow to learn was surprising in a man with so much drive but he was quick to recognize and use outstanding ability in his associates or subordinates. Some self-educated men find it difficult to work with others who have had the advantage of some higher form of education. Mr. Budd had none of this difficulty and his resourcefulness in finding work for these men which would fully utilize, or even exceed their capacities, sometimes occasioned a slight sense of dismay in them and of amusement in the onlooker.

His interests entered so many fields that his aims could be realized only by utilizing the knowledge and the skills of a large and varied group of experts. He was an organization man to an unusual degree and the experts engaged for this special work were regarded by him as a part of the Budd team. Those who worked with him were encouraged by his support and found him unfailingly generous in giving credit for their contributions. To every problem, he brought a sense of urgency, energy and interest. It is easy to understand why his associates shared his hopes so earnestly.

It is a commonplace to say that industrial technical problems are often difficult to solve but Budd possessed, in large degree, the tenacity of purpose so necessary to their ultimate solution. This was uniformly true of the problems he considered worth solving but he had no hesitation and no misgivings in rejecting the trivial or unimportant. It was probably because of this that he was so successful in selecting worthwhile projects.

On the social side he was very much interested in the activities of his church. He greatly enjoyed the society of his friends at home or at one of his local clubs. He was very fond of the theater and of music. His circle of acquaintances was very large but his friends were few and their relations delightfully open and sincere.

Edward Gowen Budd will be remembered in a variety of ways but by many he will be recalled as an industrial pioneer with an unusually progressive outlook in commercial, technical and social fields. He put a high value upon intelligent productive effort. He was always concerned for the well-being of all persons connected with his Company.

That our material possessions and our creature comforts come to us mostly as a result of hard work, he would concede and regard as being in every way fitting. His family, out of love for him and respect for his memory, have established this lectureship. It would probably be his wish that future lecturers in this series be guided in the choice of a subject chiefly by a wish to serve mankind.

A quotation from his High School graduation essay gives us a glimpse of the man. He was probably seventeen or eighteen years old when he wrote it:

> When we select our occupation, let us be diligent in attending to its duties and ambitious to do well in it, but let us not neglect other duties that pertain to the cultivation of the heart and mind.

FEED-BACK IN MAGNETIC AMPLIFIERS.

BY

ALAN S. FITZGERALD.[1]

Part II.[2]

BINARY STABILITY.

The arrangement of Fig. 9, when the circuit constants are adjusted so as to give the characteristics of Fig. 11, is capable of manifesting a most interesting type of action, similar to that of the familiar "latched-in" type of electric relay.

This effect may, perhaps, be more easily described and explained by referring to Fig. 17, which shows an exact electro-mechanical analogue

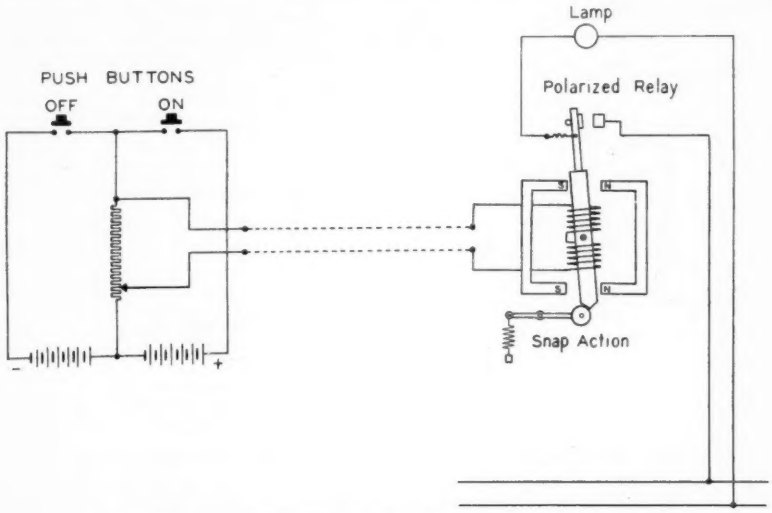

FIG. 17. Electro-mechanical analogue of application of binary stability.

of the action which is possible with a saturating reactor circuit under conditions of binary stability.

In Fig. 17 a load or indicating device such as a lamp, is controlled by means of a polarized relay which has a snap-action spring control arrangement so that the armature cannot remain in mid-position but snaps one way or the other according to the polarity of the d-c. current

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[2] Part I appears in the JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 247, No. 3, March, 1949, p. 223.

applied to the coil, and always remains in the position of the last operation when the control current is withdrawn. The relay is controlled over a two-wire circuit by means of two push-buttons and a mid-tapped battery, so that the coil of the polarized relay may be energized at will with a signal of either polarity. Obviously, pushing one button down momentarily will cause the lamp to light and to stay lit. Operating the other button will put the lamp out, which condition will be retained until the "ON" button be again actuated.

At first thought it would almost seem that a physical movement, or a change of position of some material member, is a functional necessity inherent in such a system.

However, exactly similar action is manifested by the arrangement shown in Fig. 18, in which the lamp is energized from the circuit of Fig.

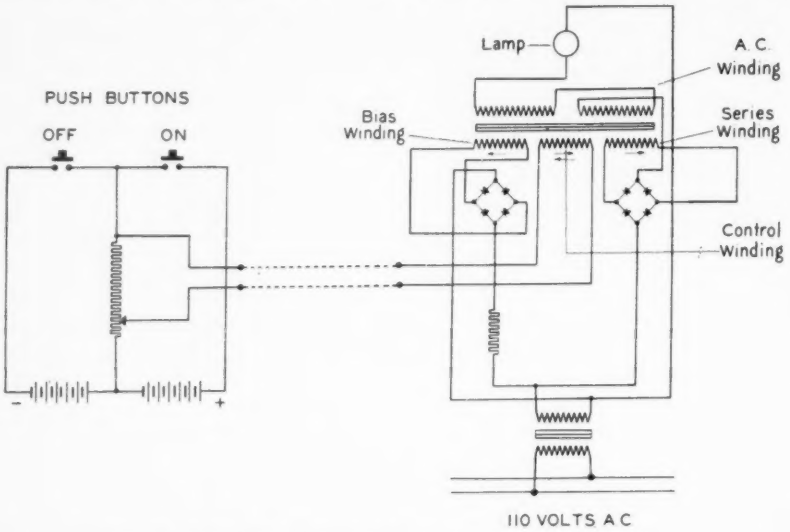

FIG. 18. Application of binary stability principle to control circuit.

9, the input coil of which is energized by the same battery and push-button arrangement as in Fig. 17. There are no moving parts in this system and all the circuits are permanently closed with the obvious exception of the signal-emitting device, duplicating that of Fig. 17.

If the circuit is adjusted in accordance with Fig. 11, when the "ON" button is depressed the lamp lights. When the button is released the lamp remains illuminated. If the "OFF" button be now operated, despite the fact that the magnetic amplifier circuit remains connected to the power supply, the lamp will appear to go out; that is to say the current will be reduced to a low level insufficient to cause the lamp to emit any visible light. After the "OFF" button is released the lamp remains out.

It is believed that it will be apparent to the reader that this action logically results from the characteristic illustrated by the curve in Fig. 11 and that further explanation will be unnecessary.

The analogy between this magnetic amplifier circuit and the electro-mechanical arrangement of Fig. 17 is maintained under another operating condition in an even more striking manner. If the a-c. supply to the magnetic amplifier circuit in Fig. 18 be interrupted, when the power is restored, neither push-button having been operated in the meanwhile, the action existing at the moment of disconnection will be reproduced. If the lamp was not illuminated when the power was withdrawn, it will not light up when it is restored. But if the light be on when the power was disconnected, as soon as the circuit is again energized with a.c., the lamp lights up again.

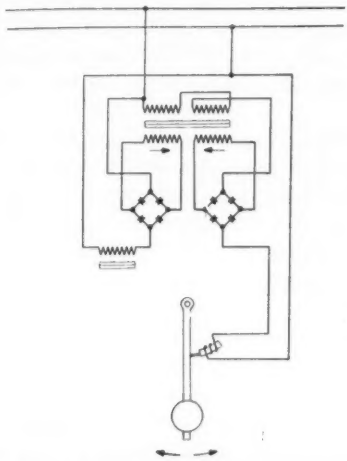

FIG. 19. Binary stability principle used for pendulum drive.

Furthermore, if the signal be applied at a time when the magnetic amplifier circuit is de-energized, whether or not the lamp will light when the a-c. power is restored, can be pre-determined.

This "memory" action is due to a residual magnetism effect in the core.

The application of an input signal of reversible polarity is not, however, the only effect by means of which the binary stability circuit may be caused to transfer from one range to the other, and therefore to undergo a change in current value of substantial amplitude. A study of the curves of Figs. 5, 6, 7, and 11 will indicate that there are a number of different changes in circuit constants that can cause such a transfer.

For example, if we refer to Figs. 5, 6, and 7 it is apparent that a modification in the amount of feed-back such as might cause the circuit

characteristics to change from, say, Fig. 5 to Fig. 7 can cause this transfer. This may be seen to be the case, for instance, at the portion of the curves corresponding to an input excitation in the neighborhood of −1 ma. Such a result could occur if the feed-back turns be changed from 450 to 350.

However, it has been pointed out that the feed-back is a function of the output circuit resistance as well as the turns. The same result might take place if instead of changing the feed-back turns, the resistance or impedance of the load circuit be modified.

Figure 19 shows an intriguing application of this principle. A pendulum is provided with an actuating solenoid having a suitably shaped plunger mounted upon the pendulum and entering and retracting from the solenoid coil as the pendulum swings.

The reactance of this solenoid winding will, of course, vary as the plunger enters to a greater or less extent into the coil. When the plunger swings fully into the coil the reactance will be relatively high; when it swings in the other direction a lower value of reactance will result.

In Fig. 19 the solenoid winding is energized from a binary stability type circuit such as has been described. It is clear that an increase in the reactance will reduce the effective feed-back; and that, conversely, the feed-back will be greater when the impedance is less. It follows therefore that the feed-back will decrease when the plunger swings fully into the coil and will become greater when it swings in the outward direction.

Clearly, if this merely caused a more or less proportional variation in the current in the coil, no effective dynamic action could result. However, in the arrangement of Fig. 19 the circuit constants can be adjusted so that the movement of the pendulum results in the discontinuity effect whereby the circuit transfers from one stability range to the other, and back again; this causes not a gradual, but an abrupt and substantial, change in current due to the plunger movement. That is to say, at a certain point on the outward travel of the plunger the current suddenly increases several hundred per cent; in like manner as the pendulum swings towards the coil a sudden change in current in opposite sense takes place.

It is clear that this relation between the plunger position and the current in the solenoid coil, and accordingly the pull exerted thereby upon the plunger, which pulsates in synchronism with the swing of the pendulum, has the characteristics necessary to drive the pendulum. Thus, once the pendulum is started swinging motion is continued as long as the circuit is energized with alternating current.

While it is not obvious that this device has any great value in horology, nevertheless it forms a very simple and inexpensive action device for display or other purposes where an oscillating movement

may be of interest. The absence of any contacts should be favorable to reliability.

It is also of possible interest as a generator of pulsating electrical effects of more substantial magnitude since, by further stages of magnetic amplification, the pulsating current in the circuit of Fig. 19 may be stepped up to substantial power levels. For example, instead of the pendulum, an oscillating system based upon spring instead of gravity control, may be used to provide an electric hammer or riveter.

It is, however, by means of this binary stability circuit principle, possible to produce a sustained pulsating effect without any mechanical moving element. If a pair of circuits of the form shown in Fig. 9 be

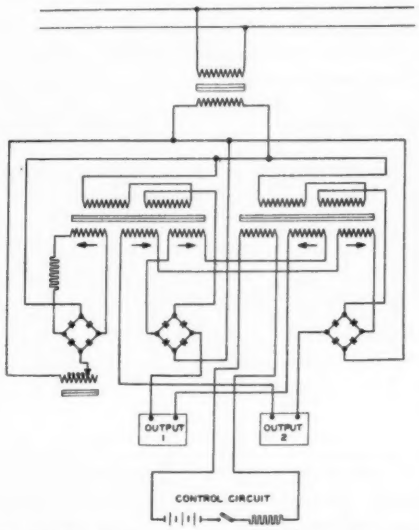

FIG. 20. Oscillating or pulsating magnetic amplifier circuit.

connected together so that each one acts as a teaser for the other, it is possible to arrange for mutual interaction such that the dual circuit continues indefinitely in a condition of oscillation or pulsation.

Such an arrangement is illustrated in Fig. 20 (1).[3] In this diagram it will be noted that the output circuit of each of the duplicate magnetic amplifier elements is connected in series with the input circuit of the other one. Thus when the right hand unit transfers from the lower range of stability to the upper range it delivers a signal to the left hand unit such as to cause this likewise to change from the low value to the high current value. This in turn energizes the input of the right hand unit in the opposite sense throwing the latter back into the lower sta-

[3] The boldface numbers in parentheses refer to the references appended to this part of the paper.

bility range. This closed-cycle chain reaction continues as long as the circuits are energized from the a-c. source. Special features may be included in the bias circuits for inhibiting the pulsating effect or for permitting it to occur. Other circuit adjustments may be included which

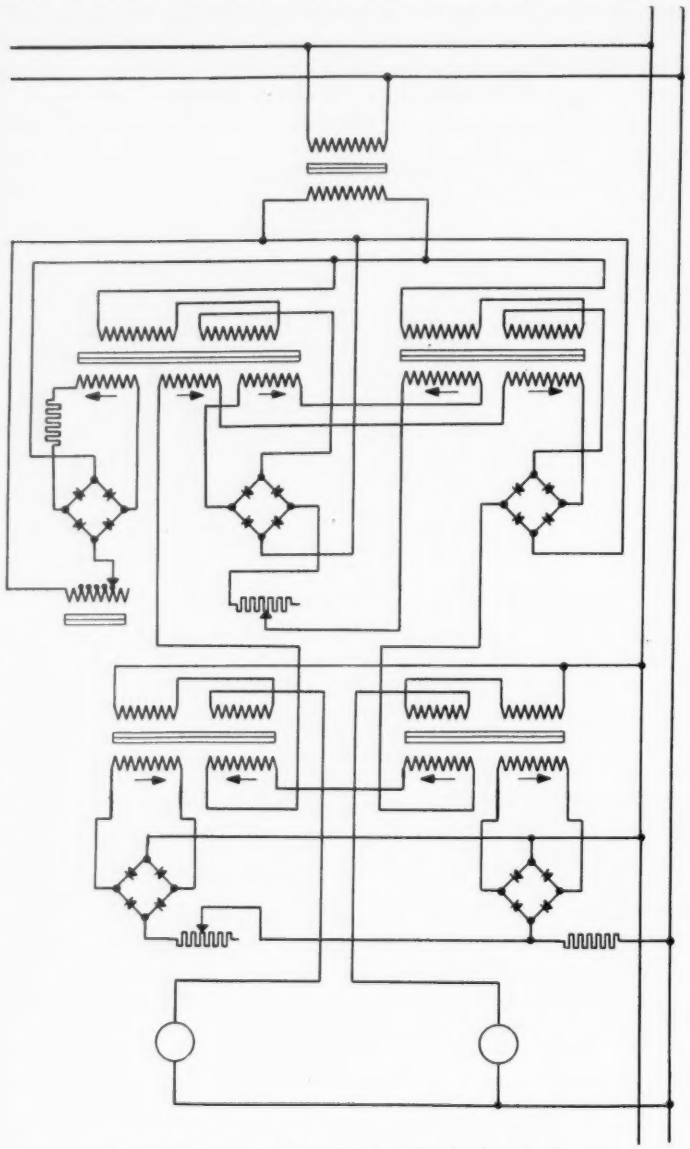

FIG. 21. Lamp control application of pulsating circuit.

have the effect of modifying in some degree the type of dynamic action which ensues. For further details of these arrangements reference is invited to the citation.

An application of this latter principle is illustrated in Fig. 21 (1). In this arrangement one of the output currents of the system shown in Fig. 20 is connected in series with the input windings of a pair of single magnetic amplifier stages of the compensating winding type shown in a previous paper (2).

Each of the output circuits of both of these magnetic amplifiers is connected to a signal lamp.

The input windings of the pair of amplifiers therefore both receive identical signals consisting of a uni-directional current continuously pulsating between a high and a low value. Both of the lamp amplifiers are identical except that the compensating currents are not adjusted to like values. In one case, the compensating excitation is adjusted to be equal to the input signal when the current is at its minimum value; in the other case, the bucking ampere-turns are made equal to the maximum value. Thus one of the lamp amplifiers will deliver only a very low current when the signal has its minimum value and the lamp will be lighted when the input current has its high value. The other lamp, however, will be out with the high value of the pulsating current and on when it has the minimum value.

Thus the two lamps will flash alternately in the manner of the familiar grade crossing danger signal. This complete arrangement, it will again be noted, has the reliability feature of complete absence of contacts or moving parts.

MODULATING CONDITION.

This phase of the behavior of feed-back type magnetic amplifiers is probably of the greatest potential value in that it makes possible amplifiers having very accurate linear response characteristics.

We shall now consider more specially the action of the circuit of Fig. 9 when the circuit constants are chosen so as to provide the response characteristics of the type shown in Fig. 12.

Figure 22 shows the circuit of Fig. 9 with the addition of an output circuit which includes a milliammeter and an adjustable series resistance, together with a push-button arrangement similar to that of Fig. 18 for furnishing an input of reversible polarity. A second adjustable resistor is provided for determining the value of the bias current.

Assuming that the type of rectifier and the number of series or feed-back turns are suitably chosen, and that the resistance of the load or output circuit is somewhat less than the optimum value, the action of the circuit can be controlled by the two adjustable elements, the bias resistor and the series resistor. The latter serves as a trimmer; it may be of a low value as compared with that of the output circuit, and such

as enables the sum of the trimmer and the output circuit resistance values to be varied somewhat above and below the estimated optimum output circuit resistance.

In order to secure the desired characteristics these two controls are to be adjusted with some nicety. The exact values which are required are determined by observing the behavior of the pointer of the milliammeter. As described above when the adjustments have been correctly made this instrument gives an indication of indeterminate value; that is to say, it behaves like a flux-meter or other uncontrolled type of instrument.

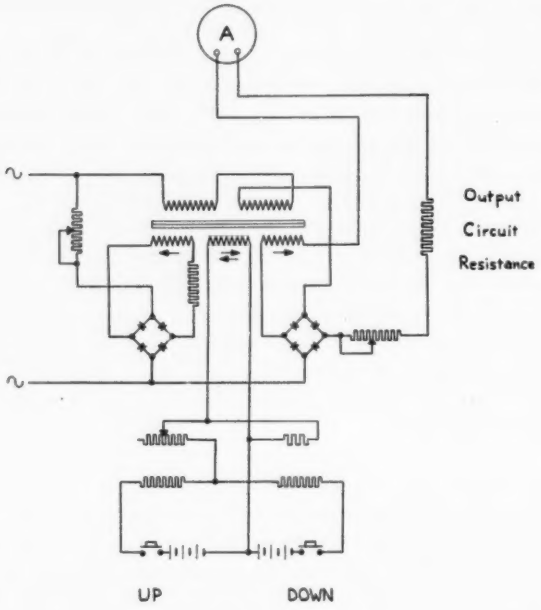

FIG. 22. Modulating circuit.

It will be recalled that the floating condition which is desired, and which is illustrated by the curve in Fig. 12, lies between the singular stability characteristic of Fig. 10 and the binary type of response of Fig. 11. Clearly, if the adjustment departs from the optimum in one direction the action will tend towards singular stability, and if the adjustment deviates in the opposite sense, there will be an approach to the binary condition of stability.

In each case the behavior of the instrument pointer will be characteristic of the sense of deviation.

It is believed that a description of the relation between the circuit adjustment and the action of the instrument pointer may possibly be

somewhat simplified by consideration of the visual aid or analogue shown in Fig. 23. The action of the meter pointer, in response to a slowly varying signal, may be compared with that of a circular object rolling on an approximately horizontal curved surface.

As suggested by the diagram the roller rests on the upper surface of a containing member capable of being tilted in either direction. Nine concepts of this structure are illustrated. It is shown as having a concave, flat, or convex surface. It is also shown in three different positions, tilted to the left, horizontal, and tilted to the right.

There is a close analogy between the manner in which the pointer of the milliammeter responds to a signal applied to the input of the amplifier, and the way in which the roller will behave if a force be applied to it laterally, tending to displace it to the right or to the left.

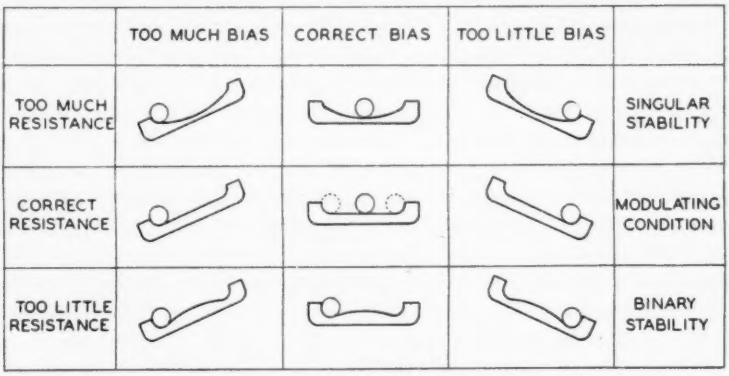

FIG. 23. Mechanical analogue of action of modulating circuit.

Similarly, adjustment of the bias current in the electrical circuit corresponds closely with the effect of a tilt in the mechanical counterpart shown in Fig. 23.

For example, suppose we first consider the case of a concave surface. If there be no tilt and in the absence of any controlling force brought to bear upon the roller, the latter will take up a position at the lowest point of the curve, approximately at the center. If, by the application of an external force, it be displaced from this position it will return there when the force is withdrawn. This is clearly a case of singular stability and corresponds with the action of the electrical circuit when this is adjusted in like manner, that is to say, when the circuit constants are such as to produce a tendency towards the characteristics of Fig. 10.

In Fig. 22 the push-button which emits the positive signal is marked "UP" and the other one "DOWN." The explanation of the action which follows refers specifically to very weak signals, under which condition the phenomena to be described are manifested. Accordingly, a low

resistance is connected in parallel with the input winding for the dual purpose of precluding opening of the input circuit by the push-buttons, and to limit the current in the input winding to a very low order of magnitude. A variable series resistance of relatively high value permits the signal level to be controlled with convenience and precision at the desired low values.

In the absence of any signal the bias is adjusted so that the meter reads at mid-scale. If now the "UP" button be held down so that a positive signal of a low value be delivered to the input of the amplifier, the meter pointer will be deflected to the right. When the button is released the pointer will return to its previous position at mid-scale. Exactly similar action in the opposite sense will result from the operation of the "DOWN" button.

If the bias current be increased the meter pointer will have a normal position somewhat to the left of or below mid-scale. Similarly if in the mechanical analogue the surface be tilted to the left the normal position of the roller will likewise be more to the left. Decreasing the bias current gives an increased reading on the meter in the same way that tilting the surface to the right displaces the roller to the right.

Let us now consider the action when the surface is convex. In this case it will not be possible to retain the roller in the centre of the surface without the application of an external force. It will tend to remain either at one or the other end of the convex surface. If by applying an external force it be removed from either extremity, when the force is withdrawn it will, if the surface is not tilted, roll towards whichever of the two ends it is nearer.

In the same manner, if the electric circuit be adjusted such that the binary stability condition obtains, the pointer of the instrument will not remain in mid-scale. It will take up a position towards the high or low reading end of the scale, and it will only be possible to transfer it from one position to the other by means of an input signal of sufficient magnitude of either positive or negative polarity as may be required.

If the bias current be increased it will require a stronger positive signal to move the pointer from the low to the high reading position; but a signal of reduced strength will be sufficient to transfer it in the downward direction. This corresponds with a tilt to the left. Reducing the bias has the opposite effect corresponding to a tilt to the right; that is to say, it will be easier to move the pointer in the upward direction than downward.

If now the circuit constants be adjusted to an intermediate condition so that the desired "floating" action is approached, the instrument pointer will behave in the following manner. If we operate the "UP" button and apply a fairly strong positive signal the instrument pointer will move towards the right, indicating an output current value in the upper portion of the scale. If we then release the push-button the

pointer will be seen to remain in the vicinity of the latter position for a substantial period of time. Ultimately it will tend very slowly to drift away from this position.

If on the other hand we apply a negative signal by operating the "DOWN" push-button the pointer will be deflected towards the left and will take up a position indicating a low current value. And again, when the push-button is released the pointer will remain for a substantial time at or near that position.

In like manner if the pointer be positioned in mid-scale as may be done by suitably operating the push-buttons, it will retain this approximate position when the positioning signals are withdrawn.

Suppose now we apply a very weak signal. If this signal be of positive polarity the milliammeter pointer will be observed slowly to move towards the right, that is to say, in the direction of increasing output current. If the push-button be operated intermittently the pointer may be "inched" or "jogged" upwards. So long as the push-button is depressed the pointer will move to the right. When the push-button is released the movement will stop. Exactly the same action will be noted in the opposite direction if the other push-button be operated so as to apply a weak negative signal.

Under these conditions the action of the circuit will correspond to the condition suggested in the mechanical analogy when the surface is approximately both flat and horizontal. If the roller be displaced in either direction there is no strong restoring force tending to return it to the central position, as when the surface is concave; or tending to cause it to move either to the right or left hand extremity, as is the case when the surface is convex.

Continuing to consider the mechanical analogy, it will be evident that the force necessary to displace or position the roller when the surface is flat and horizontal, will be very much less than that which is required when the surface is curved or inclined.

Correspondingly, therefore, when the electrical circuit is adjusted so as to give the "floating" action, and has exactly the proper amount of bias, the pointer may be displaced or positioned by means of a signal of much weaker value than is necessary with either a singular or binary condition of stability. That is to say, the value of the output current can be controlled or modulated with transient input excitation of a very low order of magnitude.

As has been mentioned above, the optimum adjustment is arrived at by observation of the behavior of the instrument pointer. This procedure may be described with some gain in conciseness if we may refer to the action of the electrical circuit in terms based upon the mechanical analogue. Thus the correct adjustment of the bias current determines the degree of "levelness." This is indicated by the rate of movement of the instrument pointer up or down when signals of the

same magnitude but of positive and negative polarity are alternately applied. If the reading of the milliammeter goes up, in response to a positive signal more rapidly than it is reduced by a negative signal the bias should be increased. Conversely, if the pointer moves with greater speed towards the left with a negative signal but more slowly towards the right of the scale with a positive signal of the same magnitude, then the bias should be decreased.

The "flatness" of the characteristic is indicated in the first place, in making the preliminary adjustment, by whether the pointer tends to drift towards mid-scale, indicating singular stability, or whether it tends to drift to either the left extremity or to the right extremity of the scale, which signifies that the circuit adjustments are such as to cause binary stability, in the absence of any signal.

When action indicative of strongly marked "concave" or "convex" characteristic has been eliminated by adjustment of the trimmer or series resistance, indication of the degree of flatness may be deduced by noting the speed of movement of the pointer at different portions of the scale, in response to weak signals.

Thus, if the pointer is indicating a low current value towards the left hand end of the scale, and a positive signal be applied the pointer will commence to move towards the right. If with no change in the signal the rate of movement of the pointer increases, this will be an indication that there is still some "convexity" present. If on the other hand, the rate of movement of the pointer decreases, and if, perhaps, the pointer comes to rest without reaching the upper portion of the scale, it may be inferred that some degree of "concavity" is still present.

In other words, the objective which is aimed at in making this adjustment is that the application of weak signals of the same value of both positive and negative polarity should, in the first place, approach a speed of response which is equal in both directions; and in the second place, this speed of response should be substantially the same at all points on the scale of the instrument.

An electro-mechanical counterpart of the above circuit would be represented by a variable-output device such as a rheostat, driven by a reversing motor controlled by the two "UP" and "DOWN" push-buttons. With such an arrangement the output current will be determined by the position of the rheostat arm, which latter will move in one direction or the other as the motor is operated. Thus the output current will increase steadily as long as the "UP" push-button is held down; or will continue to be reduced as long as the "DOWN" button is operated: and will remain at a constant value when neither of the push-buttons is depressed.

The practical utility of this modulating circuit is not predicated upon the achievement of absolute perfection in the reproduction of the action of the above electro-mechanical counterpart. That is to say, it is

not essential that the value of the output current remain at a constant value, when there is no signal, for an indefinitely prolonged period of time. In self-balancing regulating or control systems of the type to which reference has been made above, it is of equal significance if the current value be held for moderate periods of time of the order of a minute or two. In such systems, whenever there is a deviation from the proper value to which the current should be modulated, a corrective signal is automatically set up so that the required value is continuously maintained. Indeed, in many such control arrangements the output current is not required to be regulated to a constant value but rather one subject to continuous or frequent variation. In such circumstances a perfect type of action capable of holding a current at a fixed value for long periods of time would have no pertinence.

LINEAR RESPONSE AMPLIFIER.

This modulating principle may be utilized to provide a self-regulating type of magnetic amplifier capable of giving an accurate linear response to an input signal.

Such an arrangement is shown in Fig. 24, in which the output current is continuously automatically regulated so that it bears a constant relation to the input signal. This ratio is maintained by means of a tapped resistor or potential divider which is energized from the output of the amplifier. A given fraction of the output voltage, obtained from the tap on the potential divider, is compared with the signal, and any difference between these two voltages is amplified by a polarized type amplifier and applied as a control signal to a modulator type circuit such as that in Fig. 22. Thus, the output of the modulator is increased if the voltage obtained from the potential divider tap is less than the signal voltage, or is decreased if the output is greater than the proper value.

The output of the modulator is fed to a third stage which is of the neutral type and which, because it is required that the output be reduced to zero when there is no signal, is of the counter-poise type which has already been described by the author elsewhere (3).

It has already been mentioned that, as is seen Fig. 12, the range of the modulator type circuit does not go completely down to zero. For this reason the third stage is provided with a compensating winding, the excitation of which is adjusted so that when the output of the second or modulator stage is at its minimum value the net ampere turns applied to the core of the third stage saturating reactor is zero, under which condition the output of the third stage, and therefore the current in the potential divider, is likewise zero.

The polarized amplifier used in the first stage is shown only in block diagram form in order to simplify the illustration of the principle of the linear amplifier circuit, and is of the type shown in Fig. 14.

The blocking limiter of Fig. 16 is also included. This makes it possible for the input signal to be applied instantaneously at its maximum value, or to be suddenly reduced to zero, without causing any hysteresis zero-shift in the polarized amplifier.

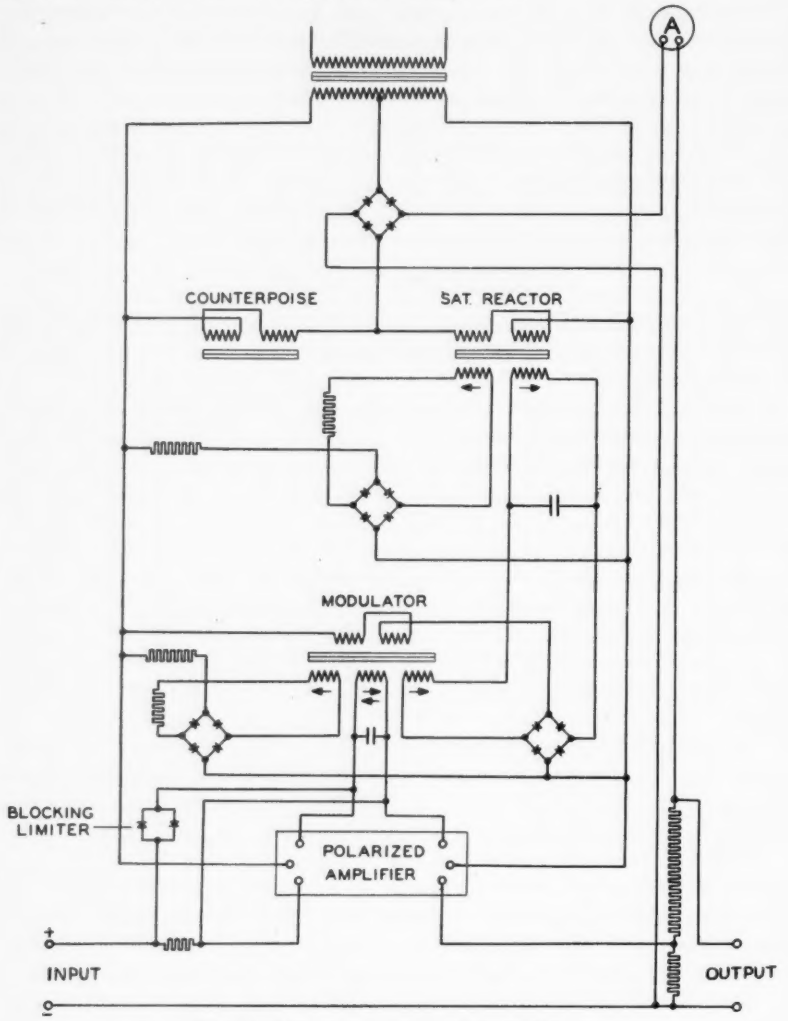

FIG. 24. Linear response magnetic amplifier.

In linear amplifiers of this type there is no difficulty in obtaining an accuracy, over the full operating range, of within one microampere. That is to say, the difference between the input signal and the fraction

of the output which should have the same value, will not, except when the signal is rapidly varying, exceed one microampere.

In order to simplify the description and explanation only a single stage of amplification is shown in Fig. 24. However, any required number of additional stages of amplification may be incorporated in the linear amplifier so as to step up the output power to any desired level. Amplifiers of this type can be built with outputs in the kilowatt range.

It will be noted that the action of the linear response magnetic amplifier is very similar to that of the rotary device known as the amplidyne. While it is possible that the magnetic amplifier may not at present compare favorably with the amplidyne in speed of response, it embraces a range of input and output power level which would require a combination of both amplidyne and electronic apparatus. It may also present some advantage in applications where, for any reason, it may be desired to avoid rotating parts, commutators, and brushes.

REFERENCES.

(1) FITZGERALD, U. S. Patent No. 2,168,402.
(2) ALAN S. FITZGERALD, "Magnetic Amplifier Circuits Neutral Type," JOURNAL OF THE FRANKLIN INSTITUTE, Vol. 244, No. 4 (1947). See Fig. 11.
(3) *Ibid.* See Fig. 10.

Errorless Bookkeeper (*The Scientific Monthly*, Vol. LXVIII, No. 3).—An automatic telephone accounting machine will soon take the argument out of the monthly telephone bills. It records the caller, the telephone called—whether local or long distance—the date, and the duration of each call to one tenth of a minute accuracy for 25,000 calls on a single roll of paper three inches wide. The first machine has been installed by Bell Laboratories at Media, Pennsylvania. Each day's finished rolls of perforated tape are inserted in a reader, a machine which assembles, translates, sorts, summarizes, and prints the record in a form to use for billing subscribers, thus eliminating most of the heavy work of telephone accounting.

New Process Makes Straw Equal to Wood for Insulating Board.—A new process for making insulating building boards from straw, which opens the way to wider industrial use of this farm residue, was announced recently by Dr. G. E. Hilbert, chief of the U. S. Department of Agriculture's Bureau of Agricultural and Industrial Chemistry.

This recent development of Department research promises to help wheat straw compete with sugarcane bagasse and wood pulp as a raw material for insulating boards and to encourage manufacturers to tap the nation's unused straw resources. About 40 million tons of wheat straw alone are now burned or wasted every year on American farms.

Their procedure consists essentially of blending ordinary straw pulp, now used in making strawboard for boxes and packing materials, with a new type of pulp which is relatively less expensive to produce and contributes increased strength and other desirable qualities to the finished product.

Conventional straw pulp is normally cooked under pressure in a chemical solution. The new pulp is made by cooking the straw in water without chemicals at atmospheric pressure and then running it through a "disc refiner," which breaks down the straw fibers into bundles of fine strands. The special properties of the new pulp are due largely to the fact that about half of its fibers are relatively narrow and slightly less than one inch long.

By blending these two pulps in varying proportions, manufacturers can produce insulating boards with a wide range of densities and other physical properties as desired. These improved straw boards have unusually high quality and greater strength at the same density than most commercial boards made from wood fiber. They also have exceptional "impact strength," or resistance to sudden blows. This is particularly important in preventing damage during handling.

The Northern Regional Laboratory's process for making straw building boards, Dr. Hilbert pointed out, requires no equipment new to board mills. The new straw boards can be formed on any of the standard board machines and dried either in tunnel or hydraulic-press dryers. The Laboratory's chemical engineers believe that with straw costing $14 per ton, delivered to the mills, the process will definitely place insulating boards from straw in a position to compete with those now made from wood.

The new process, which has been under investigation at the Laboratory for some time, grew out of extended research into the fundamental relationship between the length and diameter of wet straw fibers and the physical characteristics of finished board products.

FOUNDRIES—PAST AND PRESENT; THEIR TRANSITION FROM MANUAL TO MECHANICAL OPERATION.[1]

BY

W. H. WORRILOW.[2]

Mr. Nalle, Officers and Directors of The Franklin Institute, Ladies and Gentlemen: It is a great privilege and honor to address you this evening on the 125th Anniversary of this famous institution and after Mr. Nalle's gracious introduction you may be expecting a learned treatise on the technical side of the casting business. Instead, my talk will be more in the form of a narrative of the foundry industry, an industry with which you have all been intimately associated, perhaps subconsciously, from the moment of your birth.

Founding, or the casting of metals in a mold, is one of the oldest of arts and has been one of the slowest to emerge from the manual labor level to that of mechanized production.

Can we fail to marvel at this mechanical age, when we think that in 75 years we have released man from centuries of serf-like existence in this industry to the relative freedom enjoyed by other mechanically-operated industries?

The accurate story of casting metals is lost in the mists of antiquity. Our best authenticated records show it to have begun in Mesopotamia where warlike tribes were the first peoples to use metals cast to form. This was approximately 4000 B.C. Gold was the first metal that was given form by human hands but this was done by hammering. The first castings were of bronze.

From Mesopotamia the art spread eastward to India and China. The Bronze Age reached its highest development in China during the Shang dynasty, about 1500 B.C. Chinese founders specialized in casting huge images in bronze.

Iron casting was begun in China during the eighth century before Christ. The earliest sand mold has been traced to 645 B.C. in China; prior to that they used stone molds and various other crude methods to give form to the objects which they made.

From China the knowledge of casting spread to Japan where the records of casting date from 1000 B.C.

The Hindus developed cast steel. This was a type of blister steel, produced in a crucible. The date of this development is five hundred years after Christ, at approximately the same time that Europe was reverting to the near-savagery of the Dark Ages. The processes by

[1] A talk presented at the Annual Meeting of The Franklin Institute, January 19, 1949.

[2] President, Lebanon Steel Foundry, Lebanon, Pa.

which the Hindus made steel were never revealed to the West, since the Eastern world shut itself off in the tenth century after Christ. It was not until the eighteenth century that Benjamin Huntsman, in England, perfected the process of making crucible steel.

The Western world of antiquity embraced the eastern shores of the Mediterranean Sea. Palestine and Egypt were aware of the metal casting arts as early as 2800 B.C.

At the time of the building of Solomon's Temple a contract was given to Hiram Abith, the Chief Artisan of Hiram, King of Tyre, a city in the country now known as Lebanon. This Hiram was "skillful to work in gold, and in silver, in brass and in iron." Should you wish to know more of his accomplishments I refer you to the Seventh Chapter of First Kings in the Bible and learn of the marvelous castings he made in brass. I doubt whether, to this day, they have been excelled. The foundry in which the castings were made was in the valley of Succoth as the size and weight of the castings precluded the use of the ordinary foundry building of that day. We assume that Hiram was an educated slave of exceptional mentality and engineering skill, and that all of the men employed by him were also slaves, varying in ability, as do the workmen of today. In those days wages were never a problem and a whip was the incentive to good work and production.

From the times of the Old Testament we move to that of St. Paul and I should like to quote you a few passages from the book "The Apostle" by Sholem Asch in which he describes the celebrated bronze foundries of Corinth at the time of St. Paul or about 100 A.D.

"Corinth was known for her bronze foundries. They had the secret of producing various alloys in perfect proportions; their slaves also had a special skill in imparting to bronze a patina suggesting great age, while at the same time the metal acquired a peculiar bell-like timbre. Corinthian bronze was valued above all other metals in the ancient world—not excluding gold.

"The workers in Corinth were trained in their special skill from earliest childhood, for only those who were long accustomed to it could endure the heat of the furnaces and could work the metal as it was poured into its molds.

"The melting furnaces were in deep caverns hollowed out in the rocks. At the farthest end was the furnace itself, and close to the furnace was the section set aside as the dwelling place of the slaves. These never issued into the light of day; their food was let down to them at the end of a rope. When one of these slaves died, his body was cast into the flames. Not human beings but moles they were, leading from childhood a subterranean life: moles of a special kind, able to endure the constant heat of the caverns, to move, labor, produce in the midst of the heat of a furnace, to pass from chamber to chamber, one hotter than the other, and to draw the fiery air into their lungs. A hot vapor forever clung

to their bodies. Face, chest, shoulders, hands were pitted and marked with innumerable scars—the result of the ceaseless torrents of metallic sparks.

"The skilled slaves of the foundry mixed the various metals in proper proportions.

"These craftsmen were treated better than the furnace slaves and because of their value were more closely watched, as the loss of one was a serious matter and they might also impart the secret of the craft to outsiders. So even these slaves were never permitted to leave the caverns, and they were chained to their beds.

"After the castings were cooled they were passed on to the cleaners who worked in the open air while other slaves, armed with metal-loaded whips, stood over them, to correct and punish mistakes, or to drive them to faster work.

"In cleaning and polishing the bronze castings, part of the process intended to bring out the special luster of Corinthian vases, demanded that women polish the metal against their own skins; thus, it was believed, the oils of the human body would soften the color of the bronze.

"After the woman's body became useless for this work she was either destroyed or allowed to wander away to die as she might."

The Egyptians developed high artistic forms and useful articles of trade. Our lost wax method of today is the same as the Egyptians used centuries ago. The cope and drag method of molding was an Egyptian contribution to the industry. Bruce L. Simpson, a keen student of the metal castings industry, declares, "Due largely to her casting ability, Egypt was able to rule the western civilized world for nearly 2000 years."

The Phoenicians were traders as well as craftsmen, the Greeks, refiners, and the Romans, imitators. Toledo Steel, made in Spain by a cementation process, enabled Rome to conquer and rule for a span of 600 years.

During the Dark Ages, from the Fall of Rome in 476 A.D. to 800, the time of Charlemagne, there was no development in any form of human progress in western Europe and much that had been known earlier, was lost and forgotten. The knowledge of founding managed to survive through the needs of the Christian Church. Bells, fonts, metal doors, and censers had to be made and founders were needed to produce them.

From the time of Charlemagne to the Renaissance, there were a few major developments in smelting processes and some in metallurgy but none in the methods of producing castings. Late in the Renaissance, 1400 A.D., came the development of loam molding and also the first book dealing with foundry practice. Its author was Vannochio Biringuccio. He is entitled to be called the father of the founding industry because he was first to publish the data available in his day.

The guild system of the Middle Ages helped to advance the knowledge of founding in various ways. Their high standards of workmanship insured the production of good castings. The guilds admitted to their membership workers in non-ferrous metals as well as those who were casting objects from iron furnaces.

Another great development of the late Renaissance was the manufacture of pig iron. This, coupled with the effects of the discovery of steam power and the greater use of water power and mineral fuels, led directly to the Industrial Revolution of modern times.

It is significant that the institution in which we are gathered came into being as a tribute to Benjamin Franklin who, of all Americans, did most to further the scientific approaches to industrial development in the early days when men brought intelligence to bear in the struggle of man against things. It was he who constructed the first stove of cast iron and his experiments with the elements led to many useful developments which aided the entire casting industry.

It is noteworthy that the steel casting industry had its early beginnings within a radius of twenty-five miles of Philadelphia and that the date of the founding of The Franklin Institute coincides with the date of the beginning of the Industrial Revolution in the United States.

Perhaps the most auspicious outcome of the many political revolutions was to free men from various types of human bondage to other men. The Industrial Revolution, still in progress while I speak, serves to free *men* from things; from drudgery, danger, disease, and economic disaster. Through inventions man is building mute slaves of the elements, forcing nature to serve, instead of slay him.

Only a few months ago I received from a Swiss friend a copy of a rare book on Mining, printed in 1621, and entitled "Bergwerk Buch" or in English, "Mining Book" by George Agricola.

The book is replete with wood cut illustrations revealing that human beings were employed to perform labor tasks which we would not assign to beasts today. Men were classified with horses and goats in determining the standards of motive power. Failure to perform one's task satisfactorily led directly to the gallows.

Except for a few elementary uses of wind and water power, every ounce was derived from living creatures.

As late as 1800 women were hitched to the trucks which hauled coal from mines in England and within the memory of many persons in this room the demands of industry placed a premium upon brawn and brute strength.

Perhaps these conditions prompted the Scottish poet, Robert Burns, to write, "Man's inhumanity to man makes countless thousands mourn."

It is my purpose on this occasion to survey the revolutions which have taken place in one major industry—the founding of metals. This

industry is unique in that nearly all of its strides toward the elimination of manual operations have been made during a single lifetime.

As one who has been identified with the steel casting industry since early manhood, I may be permitted to assess the progress made in this industry. While my closest association has been with steel foundries, I have found it necessary to know the developments in related industries such as the casting of bronze, brass, aluminum, iron, and other metals.

An historical sense of these developments grows, partly, out of my interest in Elizabeth Furnaces at Brickerville, only eleven miles from my home in Lebanon. It was there that William Henry Stiegel made castings for the Franklin stove and shipped the parts to Philadelphia for assembly. From Stiegel's day to the latter half of the nineteenth century, both ferrous and non-ferrous foundries were operated along lines which showed little consideration for the employees.

It must be remembered that prior to the Benjamin Franklin stove the only manner of heating a home, or any building, was by open wood fires, and his device for creating and confining heat was the forerunner of the varied heating devices of today, many of which have been made available through the use of castings.

To make any casting there must first be the design and here creative ability, originality, and ingenuity have played a most important part. They have given to the world methods of producing castings by the thousands per day from a given pattern and made possible the many appliances we use today as necessities.

The pattern-maker, in turn, has to make the projected design of the engineer come true and also construct his pattern for minimum manual handling in the foundry. The tools used in a modern pattern shop are the result of inventive genius to reduce the manual work of the pattern-maker and to increase his production.

Many of the designs and shapes that are requested from the foundry have become extremely complicated; but due to modern machinery these patterns can be made to appreciably greater accuracy than the hand-hewn methods that existed only a few years ago.

Molding and core-making in the early days of American foundry practice were considered highly skilled arts. These men were required to know and be skilled in many foundry operations that are not now considered within the province of the normal molder's or core-maker's classification. The early day molders were required to mix and prepare the sand by hand, tempering with water at their own discretion and cutting it and finally judging by squeezing in the hand, if it felt proper for the mold which was to be made. The judgment of the molder was final and the responsibility of a good casting was his. Today the sand is mixed and tempered by milling machinery and delivered ready for use to the molder and core-maker.

In the good old days the molder did more than make the mold;

he actually poured the metal, he shook the casting from the mold and then prepared his floor for the next day's work.

Today the molder is strictly a molder, and his efforts are concentrated on this particular phase of production.

Today scientifically prepared sand is delivered to him at his station by an overhead crane or system which allows the sand to flow by gravity into the mold which is being formed or it may be delivered into larger flasks by high-speed sand slingers.

Any spillage of sand may fall through open floor gratings and be salvaged by returning to the sand mill, which scientifically blends these materials.

The molder has been largely relieved of the arduous task of ramming and packing the sand around the pattern in the flask, as the pneumatic hammer has practically replaced the old hand rammer.

During the early days of steel castings it was considered necessary to dry all molds but around 1892 a molder in St. Louis, by mistake, poured metal into a green sand mold and when examined, it was found to be better than those made in dry sand and thus the green sand method of molding was developed.

The turning point in the development of labor-saving machinery in the foundry was the invention of the first molding machine. In 1879 Frank Reinholds in New Haven, Conn., put on the market a hand presser, which was soon superseded by a stripping machine, invented in 1880.

Charles Herman invented the first jolt machine in 1887. Pneumatic molding machines came into use in eastern Pennsylvania in 1908. Today with the many improvements that have taken place, it is possible to make as many as 400 molds of small castings in an eight-hour day.

Core-making improvements have followed the trends that have been outlined for molding, and the modern foundry supplies finished cores that are ready to be set into the core prints of the mold. Venting for the release of mold gases, has been provided on pattern boards as well as the placement of risers for adequate feeding. These steps have been accomplished during the early stages of planning. As soon as the cores are set, the flask is lowered by overhead cranes and the mold may even be clamped with automatic air clamps and is ready for casting.

This operation of casting is usually done at a remote point from the molder's station by an entirely separate service crew assigned to this operation. After the castings have been poured and sufficient time allowed for solidification, they are again conveyed by mechanical means to the shakeout. Here the flask is relieved of the sand, and the casting, after separation from the sand, is conveyed to the cleaning room. The sand returns through an automatic system in which it is reconditioned for salvaging and re-use.

One of the clearest recollections of my youth is watching a group of

three laborers in a foundry in Chester. They were notching the base, or neck, of the gates and feeding heads on hot castings which were to become coupler knuckles. One worker held a chisel, the long handle of which was crudely improvised from the limb of a tree. Later, when the casting was cooled and brittle, two other workers broke off the risers and gates by flogging. Then followed an operation which we might call machining, but it was carried on with such simple tools as the planer, shaper, slotter, and even the chisel and sledge.

I cite this as an illustration of the demands made upon manual labor in the early days of the steel foundries. Great strides have been made in the chipping, trimming, and cleaning departments.

The first pneumatic tool was invented by James A. MacCoy who, in 1889, received the John Scott Medal in recognition of his achievement. This medal was awarded upon the recommendation of the Committee on Science and the Arts of The Franklin Institute.

Cutting by torch flame, which had its origin at the time of the first World War, has eliminated the need for much manual labor. Other forms of oxy-acetylene cutting have been developed so that projections can be cut to very close contours.

Gas and electric arc welding of steel and alloys have replaced the need for blacksmithing, forge welding, and other crude methods of repair.

One of the constant problems of the foundry is the removal of sand and scale from the casting. Here again, sand is brought into play. The first sandblasting machine was put on the market in 1872 by Benjamin Tilghman of Philadelphia. The sand was played against the casting through a rubber hose under air pressure, much in the same manner that a garden hose is used to spray the lawn. Later, sand was sprayed against castings in a rotating barrel which tumbled the castings as it rotated and exposed all sides to the blast.

The tumbling process was employed before the sandblast was adapted to it. The castings tumbled with other star-shaped castings which knocked against them so that, by impact, sand and scale were dislodged. Today, in addition to normal sandblasting there is the hydro, or water method, which has been found very effective.

Heat treatment, once known as annealing while in its simpler forms, is comparatively new in foundry operations. That which was done was largely a matter of guess work, trial and error. Today heat treatment of castings, both ferrous and non-ferrous, is a closely controlled operation designed to improve the mechanical and physical properties of the castings. Temperatures must be controlled within a very narrow range and in recent years, there have been developments of better furnace installations for this purpose. Today many furnaces will operate with very close degrees of uniformity throughout the entire heating chamber. This has had a definite effect upon the uniformity of the physical properties obtained from the product.

The art of heat treatment has, therefore, become a vital part of the foundry industry. A better understanding of the metallurgical features as produced by heat treatment has made it possible to produce castings for many types of specialized services which formerly were considered impossible.

Visual examination of castings was, in the past, the only means that could be employed for investigating the quality of the product. Visual inspection is needed today and cannot be eliminated, but it has its limitations when it comes to the more critical service applications. The eye cannot detect, unaided, some of the defects that might cause the casting to fail under service conditions.

Science has supplied us with new methods of inspection. The X-ray is applied to all forms of castings which are made for critical services. This inspection is of value, not only to the consumer or purchaser of the product, but to the foundry itself, in establishing founding practice for highest quality castings. Early radiographic examination of castings was first applied only to steel castings, but today it is an accepted method of quality examination of all types of cast products.

It may be that in this atomic age we shall find that radioactive isotopes may replace the use of radium for industrial radiography. It is believed that radiography is only on the threshold of industrial application. A two-million volt X-ray machine has proven its worth for heavy types of work and the betatron, using 20 million volts, has distinct possibilities for commercial radiographic examination.

Magnetic particle testing, known as "Magnaflux," is a recognized method for testing castings which have magnetic qualities. This type of inspection reveals only surface blemishes and defects and does not replace, but rather supplements, radiography.

Fluorescent inspection, known as "Zyglo," is used to inspect the surfaces of castings which do not have magnetic qualities. It has been facetiously referred to as the dermatologist of the metal industry.

The latest non-destructive testing method employs the use of supersonics having the ability to disclose defects in heavy sections and determine their approximate location within the piece. Its application to the inspection of castings has been limited, since some refinements of the equipment for the process are apparently needed before the application becomes better understood and generally applied to production castings.

We have discussed some of the mechanical operations of the modern foundry, contrasting the high degree of their development with the simple and burdensome process of former times. However, we have not as yet discussed the improvements which have come to pass in establishing more sanitary and wholesome working conditions generally.

To protect the man who pours the liquid metal from sparks and spillage, he is provided with goggles for his eyes, gloves for his hands, and

leggings for his legs. The fumes, gases, and dust which once characterized a foundry are dissipated through exhausts which serve to cleanse the air and moisten the dust so that it becomes a sludge for easy handling and disposal. Some foundries have found it feasible to install air-conditioning, controlling temperature and humidity, and resulting not only in improved working conditions, but also in improving the quality of the product.

There are some persons who are prone to make statements derogatory to management in the founding industry. To such I make the suggestion that they visit an up-to-date foundry and then know whereof they speak before they assail us. Let them see the rest rooms, dispensaries, lockers, and showers.

It would profit laymen if they were to visit the foundries set up by the advanced and forward-thinking foundries of the day and see what a transformation has taken place in the last fifty years.

In my opening remarks I referred to the fact that we lived with castings from the moment of our birth and in conclusion I should like to illustrate what I meant.

In 1900 the output of automobiles was less than 5000 cars and then began the great mass production of them. Output of automobiles depended upon the production of their component parts, perhaps the most important being the engine cylinder of cast iron. At this time, three trained young men in the cast iron foundry business formed a company, Campbell, Wyant, & Cannon of Muskegon, Michigan, to specialize in these castings. They had little money but plenty of "know-how" and courage. Anticipating the ever-expanding market for automobiles, they introduced into their foundry methods and devices unheard of before, and their initiative was quickly followed by others so that you and I and the man who formerly operated the treadmill could ride in luxury in an automobile within the means of all.

There are many ladies in our audience tonight. I wonder if they appreciate how castings made possible the full-fashioned hosiery they wear? In the 1890's two Germans, Henry J. Janssen, a mechanic, and Ferdinand Thun, a bookkeeper, opened a small machine shop in Reading, Pa. From that modest beginning sprang the Wyomissing Industries, and in the foundry of one of their companies, the Textile Machine Works, is found the most modern method of making the tiny brass, aluminum, and iron castings that enter into the construction of the machines that weave your hosiery. The plant is so modern that, if it were not for the molten metal, you would hardly know you were in a foundry.

You have been annoyed when driving your car by being held up by a giant truck or bus ahead of you. Into that truck or bus have gone a myriad of castings of malleable iron, brass, aluminum, steel, and

cast iron, and neither the truck nor bus would have been possible without these castings.

Let us turn to the home for a moment. As you unlock your door, do you realize that millions of keys for this purpose are made of malleable iron, each weighing about an ounce? As you enter the kitchen you find the electric or gas ranges and stoves all made of iron castings and your refrigerator, deep freeze, and incinerator of the same metal. Enter your bathroom and you find the tub and shower, the lavatory, the faucets, all castings using iron or brass. Many bowls and vases cast of silver or other metals grace your dining-room table. How could a modern home operate without castings?

In 1888 aluminum was invented and that incomparable metal could never have been developed and exploited if it had not been for the vision of the men who directed the fortunes of the company then known as the Aluminum Company of America, familiarly known as Alcoa. The lightweight automobile and other machines in which weight is a factor, all prove its influence on modern life. Let us return to the kitchen again to see the aluminum pots and pans, knives, forks and spoons, all made in aluminum foundries unsurpassed in the United States for mechanization of production, cleanliness and the comfort of employees.

A famous engineer of a century ago and a member of the Board of Managers of The Franklin Institute, Mr. Joseph Harrison, Jr., published an account of the rabbinical legend of the Iron Worker and King Solomon. The volume contains a reproduction of a painting, made for Mr. Harrison, in which a blacksmith is shown seated on the throne to the right of King Solomon. The people are gathered around the throne to protest that a mere ironworker had no right to such a distinction.

According to the legend Solomon silenced the protests in the following manner:

Turning to the stone carvers the King asked,

"Who made the tools with which you carve?"

"The blacksmith," they replied.

Then to the woodworkers:

"Who made the tools with which you hewed the trees of Lebanon and formed them into pillars and roof for the Temple?"

"The blacksmith."

Then to the artificers in gold and silver:

"Who made your instruments?"

"The blacksmith."

Then Solomon turned to the blacksmith saying:

"Thou art all men's father in art. Go wash the sweat of the forge from thy face and sit at my right hand. The Chiefs of my workmen are but Men; thou art more."

I am sure that today Solomon, in his wisdom, would extend that honor to the foundryman.

RESEARCH ON READING AIDS FOR THE BLIND.[1]

V. K. ZWORYKIN,[2] L. E. FLORY,[2] AND W. S. PIKE.[2]

The problem of mechanical or other aids for the handicapped has long intrigued engineer and layman alike. The museums are full of devices meant to perform the functions of senses deprived the victims of accident or disease and the number of patents in the office on such devices is staggering. Some of the devices are amusing, most of them are hopelessly inadequate, but all were motivated by the same desire to utilize some scientific principle to take the place of the missing sense or to substitute one of the other senses. Only a few have come into general use: for example the Braille system of blind reading, the electronic hearing aid, the artificial larynx, and so on.

The handicap of the blind person is one of the most complete and of all the things of which the blind person is deprived, the inability to read is to many individuals by far the most serious. The Braille system has been a godsend to many a blind person, but it too has great limitations. The transcriptions are bulky and expensive with the result that a limited amount of material can be made available to a blind person. The talking book and other systems of conveying information to the blind, useful and valuable as they are, suffer like limitations. This then brings us to the obvious point of the possibilities of in some way making ordinary printed matter available to the blind. The idea is not new. Even before the discovery of the photo-electric and photo-conductive effects, ideas were advanced for machines using slightly raised or electrically conducting letters to transmit an impression to a blind person. With the discovery and development of photosensitive devices great impetus was given the work. The earliest record of a comprehensive attack on the problem is in the work of Dr. E. E. Fournier d'Albe who in 1914 (1) [3] described the results of several years of work on his device called the optophone, which has in reality been the basis of most all of the later work on reading devices.

Broadly speaking, there are two approaches to the problem. The first makes use of the various characteristics of the letter to directly generate some sort of signal which, in the case of an audible presentation would be in the form of a variation of frequency amplitude or modulation of some sound.

By the second method the form of the letter is recognized by the

[1] Lecture presented at the Stated Meeting of The Franklin Institute, November 17, 1948.

[2] R.C.A. Laboratories, Princeton, N. J.

[3] The boldface numbers in parentheses refer to the references appended to this paper.

apparatus and an arbitrary sound or other signal generated to indicate the letter or other character. The first method is much the simpler to accomplish technically, but puts the entire burden of recognition of the sound pattern on the ear and brain. The second method makes for ease of recognition of letters or words by the reader and relies upon more complex apparatus to accomplish the identification. In fact, it is conceivable that an instrument of the recognition type might be made, allowing sufficient complexity, to read material in intelligible English. The first method, however, is attractive because of the simplicity of equipment and the resultant eventual low cost.

As a result of the desirable features of these two methods, both have been the subject of much study and a considerable amount of development work.

The optophone of Dr. Fournier d'Albe, which was mentioned before, is of the first or direct signal generation type. Dr. Fournier d'Albe recognized that most of the information necessary to identify all of the letters is carried in five zones as indicated in Fig. 1.

Fig. 1. Analysis of print into five zones by Fournier d'Albe Optophone.

In this device he made use of five spots of light, each modulated at a different frequency so that when sounded together in any combination a pleasing chord is produced. The presence or absence of one or more of the tones in such a chord can readily be recognized by a trained ear. As the group of spots is moved along the line of print, variations in the tonal content of the chords are introduced by the black and white of the letters. This device gave a signal which could undoubtedly be read but suffered from some limitations which restricted its usefulness. The chief of these was the accuracy with which the scanning spots were required to be aligned with the type, which eliminated the possibilities of a hand-held reading stylus, and necessitated the reading material being clamped into a scanning machine.

In the case of the letter-recognition system, little is known of any early work although many proposals have been made. Quite generally they have suggested an optical matching system which would look at the letters to be identified and run through a set of letters, for instance on a drum, until the optical match of the unknown letter was found, at which time a signal would be given to activate the indicator corresponding to the letter (2).

Many methods have also been proposed for creating a raised or embossed impression of a letter by optically projecting an enlarged image

of the letter on a grid of small photocells. The photocells would each be connected in a typical case through an amplifier to a solenoid which would elevate or depress pins in response to the light or dark of the letter. The raised impression would then be read by touch as in Braille.

Many of the proposed methods are fundamentally sound from a technical standpoint, but too often neglect the subjective aspect and often require complicated mechanical arrangements for scanning.

THE DIRECT-SIGNAL-GENERATION METHOD.

In the system utilizing the direct generation of signal by the characteristic of the letters it is first necessary, of course, to use an analyzing system which will examine the letter in sufficiently fine detail to obtain the distinguishing characteristics. Once this information is obtained, it must still be presented to the mind of the reader in such a way that he can make use of it in creating the impression of the letter or word. Since language conveys information in time sequence, as contrasted to pictorial or spatial presentation, some form of scanning will always be used to convert the positions of letters and words into time variations. If the scanning means is assumed to be a slit of slightly more than the height of the letter and of a width considerably less than the letter, through which the print may be "viewed" by the device, there are certain properties of the letter which, as seen through this slit, will vary as the slit scans the line of print. First, the total area under the slit will vary as the scanning proceeds. Second, the area is not always in a single unit but may be broken up, the number of units varying as the material is scanned. Third, the position of the area or areas along the slit is also a variable. Finally, the relative size of black areas, if more than one, will also convey information as the scanning is carried out.

Variations of these properties may be used singly or in combination to generate a sound to represent the print, keeping in mind that the information must be presented at a rate at which it can be assimilated by the reader. Assuming a reading speed of sixty standard five-letter words per minute, the letter frequency becomes five per second. This does not allow very much detail within the letter to be presented directly, since information presented in a shorter time than one-fifth second cannot ordinarily be utilized unless it is repetitive; in which case the rapidly presented information is then modulated into a pattern by the letter shape, the pattern or variations in the higher frequency being recognized. By the same means, word patterns are built up by the modulation of the higher frequencies making up the letter sounds and may be recognized as units.

The simplest method of approaching the signal-generation problem is by the use of a single vertical slit which is manually scanned over the line of print. The relative area of the slit covered by the black part of the print can then be used to give an audible signal, which may

be a tone varying in amplitude or frequency (or both) with the amount of black. This gives information at a convenient rate, but a consideration of Fig. 2, which shows the variation in total area under the slit with time, will indicate many ambiguities such as *b*, *p*, and *h; d* and *q; n*, *u* and *o*, etc. Multiple slits or a divided slit may be used to resolve some of these difficulties as was done originally by Fournier d'Albe.

Another approach to the resolution problem is the introduction of vertical scanning at a constant rate by means of a small spot. Manual scanning along the lines in the usual way then provides complete coverage of the letter, converting each detail into an electrical signal, in a manner analogous to the scanning process used in television. The generated signal may then be used to control or modulate an audible signal. In this way, the finer detail of the letter, although represented

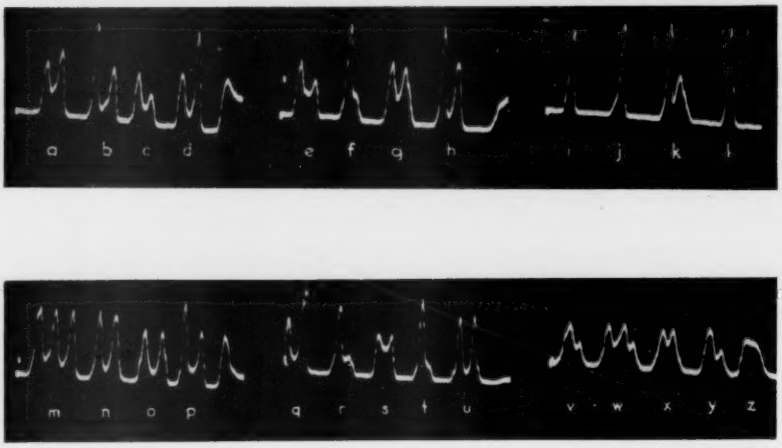

Fig. 2. Variation in black area as letters are scanned by simple vertical slit.

by a rather short time duration, is repetitive and is further modulated by the letter shape as manual scanning proceeds, so the ear can detect the variation of the higher frequencies. This method can resolve the letter in as great detail as desired, and its utility is determined by how successfully the information can be transmitted to and interpreted by the brain.

Considerable development work has been done on an instrument of this type at RCA Laboratories under the sponsorship of the committee on Sensory Devices of the Office of Scientific Research and Development and the National Research Council (3). In this device a spot of light is caused to move up and down in a cyclic manner thirty times per second, thereby scanning a line a little more than the height of a letter. In order to provide audible indication of the position of the spot, an audio

oscillator is frequency modulated in sychronism with the motion of the light spot so that when the spot is at the top of a letter the frequency is high and when it is at the bottom, the frequency is low. As the spot scans the letters, the light reflected from the paper is collected and allowed to fall on a phototube. Through an amplifier and gate tube

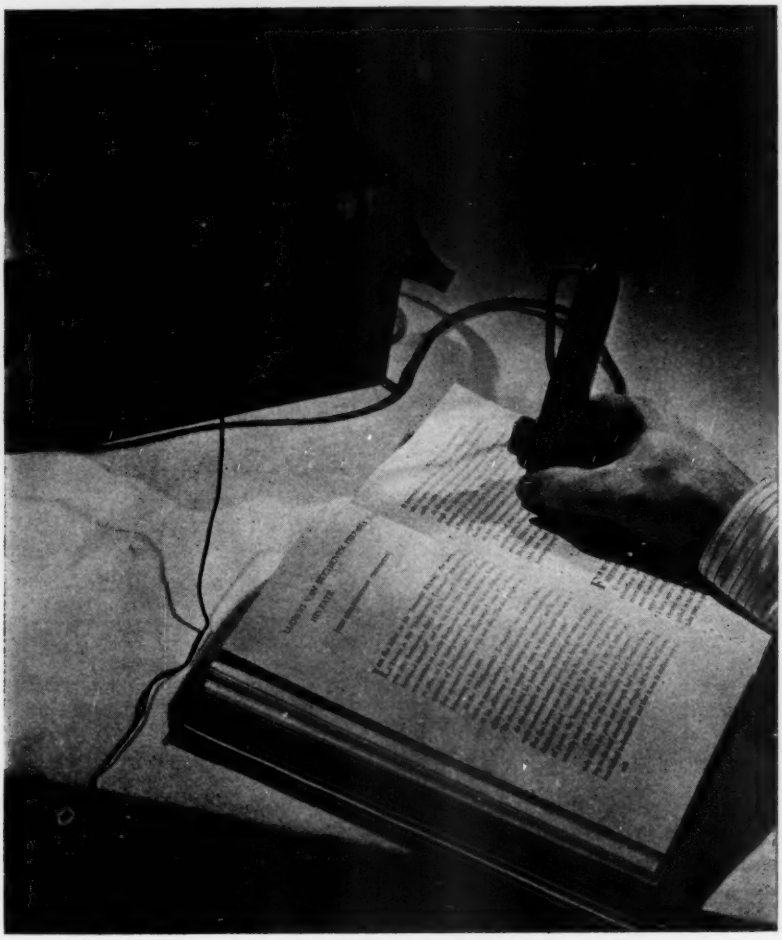

FIG. 3. Scanning type reading device, showing hand-held stylus.

controlled by this light, sound is allowed to reach the reader's ear only when the spot is on a black part of the letter. The frequency or pitch of the tone heard will depend upon the vertical position of the black area. Thus, complete information as to the number and position of

black areas under the scanning is presented by the instrument. The variation in these sounds, as the letters and words move under the scanning line, makes up the signal applied to the ear of the reader.

The instrument in its present form consists of three parts; the hand-held stylus, the case containing the batteries and signal generating means and the ear piece with which the reader receives the signal. The instrument is shown in use in Fig. 3.

The signal is generated by conventional beat-frequency methods, the two oscillators operating at about 50 kilocycles per second. A pentagrid converter stage is used as a mixer and at the same time acts as a gate to allow the audio signal to pass only in response to the signal

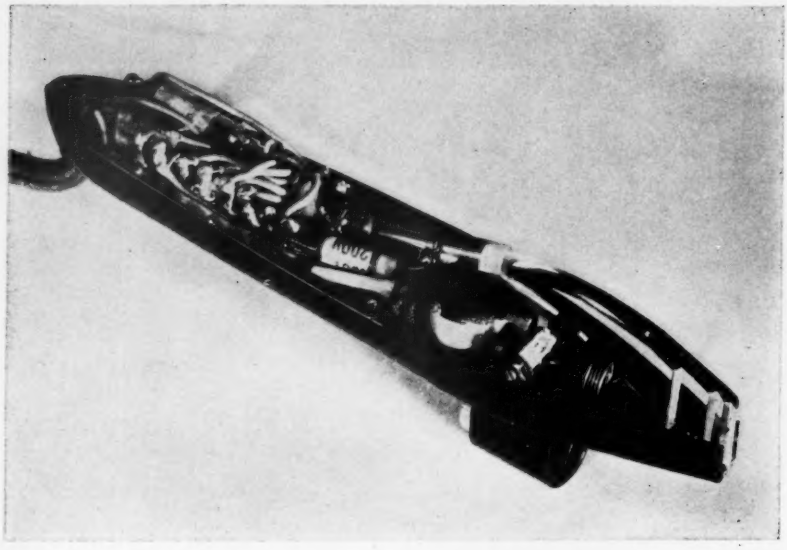

FIG. 4. Interior of stylus of scanning type instrument.

from the stylus. The frequency of one of the oscillators is varied by a special vibrator arrangement in which an armature attached to the reed forms part of the magnetic circuit of the inductance of the variable frequency oscillator. Thus, as the reed vibrates, the motion of the armature causes the frequency of the oscillator to vary. In operation the frequency is varied between 300 and 4000 cycles and the scanning rate is 30 per second.

The stylus contains a light source and projection system including a vibrating mirror for producing the motion of the spot, light collecting means, and a phototube with a two-stage amplifier. The interior of the stylus is shown in Fig. 4. In this view can be seen the lamp housing,

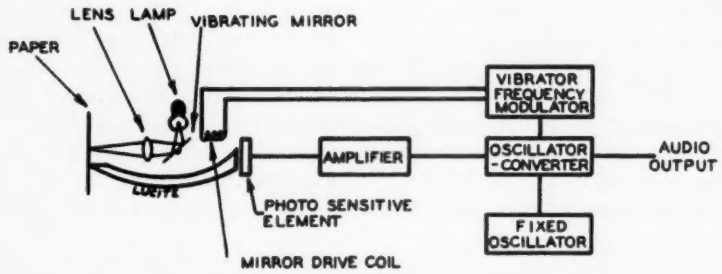

FIG. 5. Block diagram of elements of scanning type instrument.

mirror, lucite light collector, phototube and amplifier. A block diagram of the instrument is shown in Fig. 5 and a schematic in Fig. 6. An oscillographic analysis of the signal produced by this instrument is shown in Fig. 7 for comparison with Fig. 2. Of course it must not be assumed that the identification of the letter is correspondingly facilitated, for the information representing the fine detail of the print in Fig. 7 is presented at a much higher rate, and it is necessary to rely on the formation of sound patterns for identification as was indicated in the earlier section.

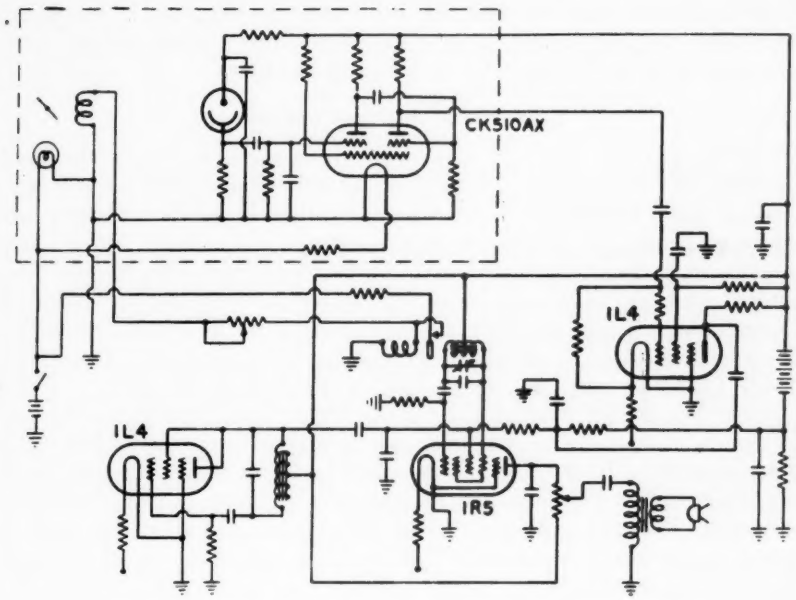

FIG. 6. Complete schematic diagram of scanning type reading device.

Tests with blind subjects have shown that a reading speed of at least twenty words per minute can be reached with the instrument under favorable conditions. In most of the tests a guide in the form of a straight edge, as is used in drafting, was used to keep the stylus on the line, the reader finding the line with no mechanical assistance. It was found possible, however, for the subject to read, at a reduced rate as yet, with no guide whatever. This is possible because the scanning line can be made a little longer than the height of the letter so that some

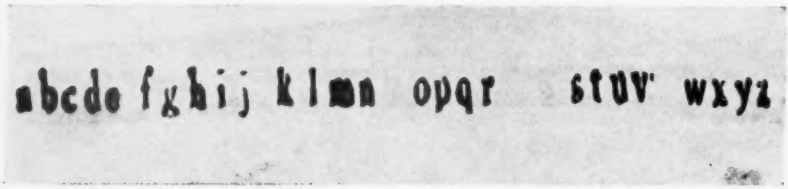

FIG. 7. Oscillogram of output signal from scanning type reading device.

tolerance is allowable in the relation of the line to the letter, since the character of the signal does not change as long as the letter is completely scanned. The pitch of the signal does change, however, as the stylus tends to wander from the line, and it is this change in pitch which occurs before the deviation is serious that gives the reader a clue that he is wandering and enables him to make correction. The reading tests with the instrument have been very limited in scope and considerable more work with blind subjects is in order.

THE LETTER-RECOGNITION METHOD.

As was pointed out earlier, the letter-recognition system is designed to determine completely the identity of the letter electronically and produce some identifying signal which can then be used to control any arbitrary sound, as, for instance, to pronounce the letter. The early thinking on letter-recognition devices is best exemplified by the Sharples patent mentioned previously (2). In this system an optical image of the letter is projected in the plane of a moving stencil, such as the surface of a rotating drum, in which are cut transparent replicas of the letters of the alphabet. As the drum rotates, light from the image of the printed page passes through the cut-out letters until the exact match of the letter being "read" is reached; at which time the image of the black letter exactly fills the cut-out opening and the light transmitted is sharply cut-off. The light passing through the mask is picked up by a phototube and the sudden drop in light upon coincidence is used to operate appropriate reproducing means to produce the desired sound.

Another system of recognition makes use of an electrical device which was developed in connection with work on electronic computing

devices for recognition of unique combinations of potentials. This system has been the subject of an investigation also under the National Research Council (4), hence, will be described in considerable detail. In this system, the letter is scanned vertically with a spot of light as in the instrument previously described, except that the scanning is done at a much higher rate ($\cong$ 500 cycles per second) and is not continuous but rather is in step-wise fashion so that in effect the spot pauses momentarily at several points along its path, creating the effect of a series of spots arranged in a vertical line. Due to the scanning, however, the spots are not present continuously, but rather appear in a time sequence which facilitates the separation of signals from the individual spots as will be seen later. If the series of spots forming the vertical line is now moved manually along the lines of type, a series of interruptions in the reflected light will be caused by the black print. These

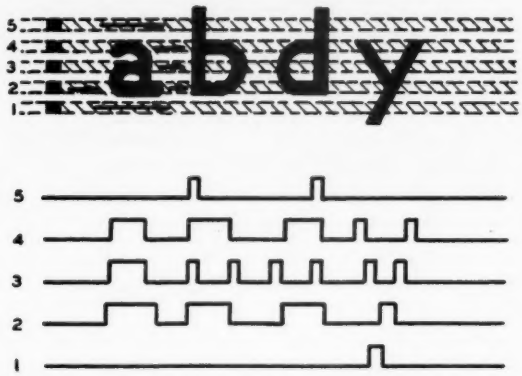

FIG. 8. Analysis of print by letter recognition device, showing pulses occurring in each zone as a result of scanning along the line.

interruptions can then be transformed into electrical impulses by means of a phototube and amplifier. As a result of the high speed vertical scanning and the manual scanning along the lines of print, the signal output of the phototube amplifier will be in the nature of a carrier of the scanning frequency, modulated by the interruptions of the light by the black parts of the letter. The interruptions in each channel can be separated out by a timing circuit since, as pointed out, the light spot appears periodically and sequentially at each of the selected points on the scanning line. The interruptions in each channel can then be counted by electronic means. If five to eight channels (spots) are used, it is found that a unique combination of pulses (or interruptions) in all channels taken together exists for most of the letters of the alphabet.

An example of the type of information obtained in each of five channels in a typical case, is shown in Fig. 8. As can be seen, there is a

definite number of pulses occurring in each channel. There is, however, an ambiguity existing in the case of *b* and *d*, in that the number of counts in every channel is in each case the same. Closer examination will show a difference in the sequence in which the pulses in the various channels occur. This sequence can be resolved and combined with the other information to identify the letter. Such an ambiguity exists for several combinations of letters and must be resolved by this method.

The heart of the letter-recognition machine is the before mentioned device known in electronic computer circles as a "function matrix."

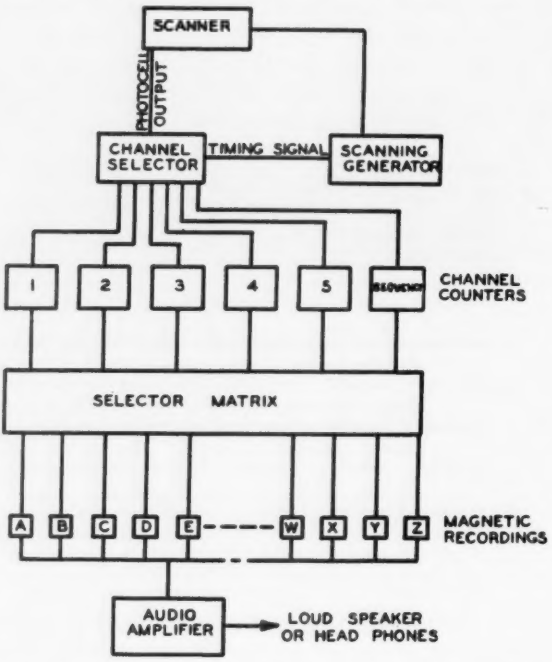

FIG. 9. Block diagram of elements of letter recognition reading device.

This matrix consists of a network with a plurality of input circuits and likewise, a plurality of output circuits. The input circuits are individually activated by the application of potentials. The internal connections are such that for a certain combination of activated input circuits one and only one of the output circuits is activated. Conversely, no other combination of activated input circuits will activate this particular output circuit.

In the present instrument, the input circuits of the matrix are activated by the counters which count the interruptions in each channel. Since no letter has more than four interruptions, twenty inputs to the

matrix will handle all possible combinations of interruptions due to scanning by five zones. (Although five zones are shown for simplicity, the actual instrument constructed makes use of eight zones for added accuracy.) To this must be added the necessary sequence information to resolve the ambiguities mentioned above. The matrix must have twenty-six outputs for direct spelling, plus any additional ones desired such as for figures, punctuation, etc.

The output from the matrix is used in the present case to operate a multi-channel magnetic reproducer arranged so that as a letter is

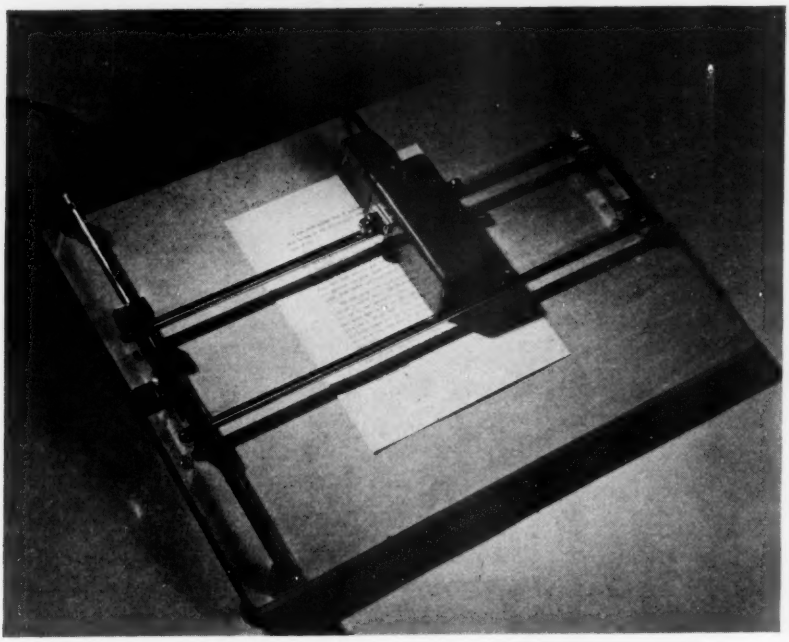

FIG. 10. Scanning head which is moved manually along lines.

recognized, the recording of that letter is released and allowed to be reproduced once only. As the letter is reproduced, a signal is sent back to the counters returning them to the start condition ready for the next letter.

A block diagram of the complete device is shown in Fig. 9.

The scanning head which contains a miniature cathode ray tube and optical system for generating the scanning light spots, as well as a photomultiplier tube for receiving and amplifying the reflected light, is shown in Fig. 10. The channel selectors, counters and selector matrix are mounted in the rack shown in Fig. 11. A forty-channel magnetic

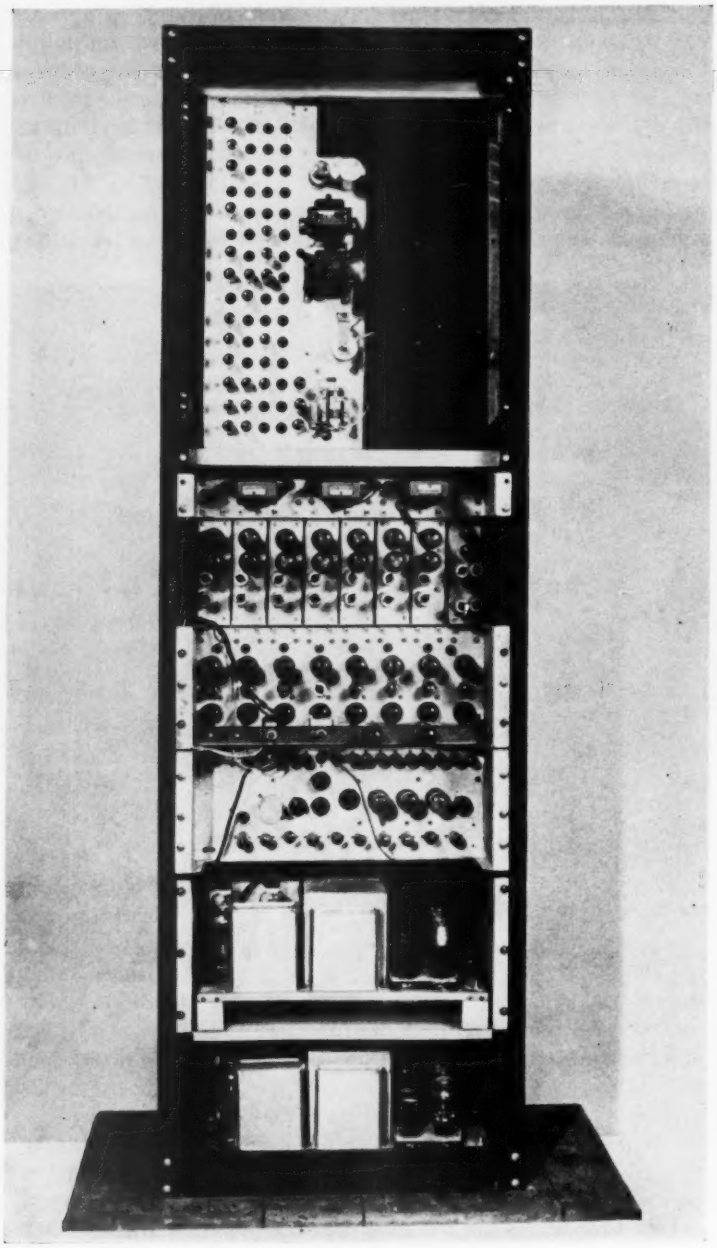

FIG. 11. Selecting, counting and recognition circuits.

reproducer, solenoid operated (Fig. 12), was constructed for this instrument. Individual letter sounds are recorded on separate disks which are friction connected to a continuously rotating shaft. A pin on the disk engages the solenoid armature preventing the rotation of the disk. On signal from the selector matrix the proper solenoid is activated, lifting its armature and allowing the disk to make one revolution. The letter signal recorded on the disk is picked up magnetically and reproduced through a conventional audio system.

Only laboratory tests have been made on the letter-recognition device. Up to the present time a special type face has been used which is devoid of all serifs and other embellishments. With this type a fair degree of reliability of operation has been obtained. The requirement of alignment of the scanning spots with the type is still very stringent and further work needs to be done to increase the tolerance in this respect.

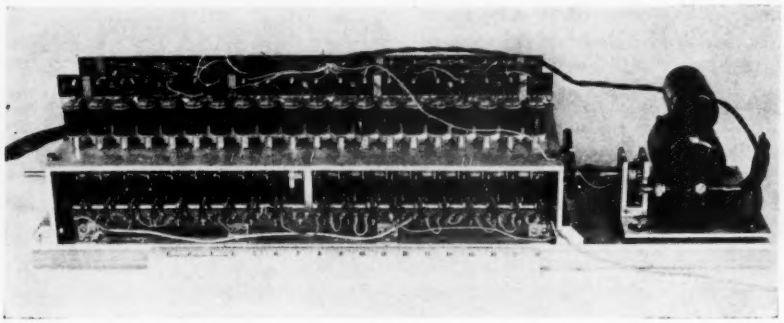

FIG. 12. Forty channel magnetic reproducer for producing sounds in response to signal from recognition circuits.

If the requirement of operation from standard type is removed an interesting possibility presents itself. It is generally agreed that spoken English with quite a high degree of shading may be built up from thirty to forty phonetic sounds. If a phonetic alphabet were designed and material to be read printed in this alphabet, the recognition device could be so designed as to reproduce the corresponding phonetic sounds in response to the symbols and thus read the material in approximate English words.

While the development of the letter-recognition device was aimed specifically at a reading instrument for the blind, the principle used is fundamentally that of recognition of a printed pattern by an electrical comparison with a prearranged standard. As such it lends itself to applications other than the one for which it was intended. The recognition circuits could be used to read any type of pattern or coded infor-

mation within its capacity. Likewise, the information once at hand need not be limited to the releasing of a recorded sound but might be used to operate some piece of equipment such as a teletypewriter or computing machine.

The results so far achieved with these reading devices, while not spectacularly successful, serve to point out the possible approaches to the problem and to emphasize the difficulties in achieving recognition both electrically and mentally. Extremely rapid reading will probably not be possible with simple equipment. Speeds of reading now considered practical for some purposes have been achieved with the direct-signal-generation device, however, and it is not unlikely that considerable improvement can still be made in this direction. Some degree of complication of equipment in the direction of the letter-recognition principle might remove some of the burden of recognition from the reader's mind without making the instrument prohibitively intricate. The present lines of approach have by no means been exhausted and many more tests of a subjective nature are in order to indicate the direction for further development.

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ON THE SECOND LAW FROM THE STANDPOINT OF THE EQUATION OF STATE.*

DISCUSSION BY

I. PRIGOGINE[1] AND P. VAN RYSSELBERGHE.[2]

The paper (1) [3] published by J. L. Finck under the same title as the present note contains a completely erroneous presentation of the thermodynamic method of De Donder (2). After having recalled that De Donder uses as additional variable the degree of advancement ξ of the chemical reaction Finck states that the expression

$$dS = \frac{dQ}{T} = \frac{dE + pdV}{T}, \tag{1}$$

is not a total differential in the three variables p, T, ξ or V, T, ξ. He then concludes that the use of the variable ξ by De Donder's method must be rejected.

This conclusion is due to the fact that Finck has not taken into account that ξ is an independent variable only for irreversible transformations as has been shown by De Donder and his collaborators (2) in numerous places of their writings. At equilibrium, on the contrary, the value of ξ is determined by the values of the physical variables through the condition expressing that the affinity of the corresponding transformation has become equal to zero:

$$A(p, T, \xi) = 0. \tag{2}$$

Hence for equilibrium transformations dS will be a total differential in only two independent variables which may be arbitrarily selected.

In the case of irreversible transformations dS must indeed be a total differential in three variables, but then dS is not given by formula (1) any more. The correct expression for dS is now

$$dS = \frac{dQ}{T} + \frac{Ad\xi}{T}, \tag{3}$$

in which the second term on the right-hand side corresponds to the

* The Journal of The Franklin Institute, making an exception of its policy never to publish discussions of papers, is printing this interchange of ideas between Professors Prigogine and Van Rysselberghe and the author of the paper under discussion, Dr. J. L. Finck. No further discussions will be accepted for publication.

[1] University of Brussels, Brussels, Belgium.

[2] University of Oregon, Eugene, Oregon.

[3] The boldface numbers in parentheses refer to the references appended to each section of this series of discussions.

production of entropy resulting from the chemical reaction. This expression is a total differential as the following reasoning will easily demonstrate:

Using the variables p, T, ξ we have (3)

$$dQ = h_{T\xi}dp + C_{p\xi}dT - r_{pT}d\xi, \tag{4}$$

with

$$h_{T\xi} = \left(\frac{\partial H}{\partial p}\right)_{T\xi} - V, \tag{5}$$

$$C_{p\xi} = \left(\frac{\partial H}{\partial T}\right)_{p\xi}, \tag{6}$$

$$r_{pT} = -\left(\frac{\partial H}{\partial \xi}\right)_{pT}, \tag{7}$$

in which H is the enthalpy of the system, $C_{p\xi}$ the heat capacity at constant pressure and composition, r_{pT} the heat of reaction at constant pressure. Let us note also that, on account of (6) and (7), we have

$$\frac{\partial C_{p\xi}}{\partial \xi} = -\frac{\partial r_{pT}}{\partial T}, \tag{8}$$

which is nothing but Kirchhoff's theorem.

We now write the conditions to be fulfilled if dS is to be a total differential. Combining (3) and (4) we have

$$\frac{\partial \frac{h_{T\xi}}{T}}{\partial T} = \frac{\partial \frac{C_{p\xi}}{T}}{\partial p}, \tag{9}$$

$$\frac{\partial \frac{h_{T\xi}}{T}}{\partial \xi} = -\frac{\partial \frac{r_{pT} - A}{T}}{\partial p}, \tag{10}$$

$$\frac{\partial \frac{C_{p\xi}}{T}}{\partial \xi} = -\frac{\partial \frac{r_{pT} - A}{T}}{\partial T}. \tag{11}$$

Formula (9) is classical. As to (10) and (11) formulas (5) and (8) reduce them to

$$\frac{\partial A}{\partial p} = -\frac{\partial V}{\partial \xi}, \tag{12}$$

and

$$\frac{\partial \frac{A}{T}}{\partial T} = -\frac{r_{pT}}{T^2}. \tag{13}$$

These two last formulas show how the affinity depends on pressure and temperature and how the affinity can be calculated.

We thus see not only that dS is indeed a total differential but also that the conditions making it a total differential lead, in De Donder's method, to interesting new formulas.

In concluding we wish to point out that Finck does not seem to be aware of the classical writings of Duhem (4) concerning the number of variables (internal and external) necessary to define the complete state of a closed system at equilibrium.

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(3) I. PRIGOGINE AND R. DEFAY, *loc. cit.*, Vol. I, Chapter IV.

(4) P. DUHEM, "Traîté Elémentaire de Mécanique Chimique," Paris, Hermann, 1899, 4 volumes. For a modern exposition, see I. PRIGOGINE AND R. DEFAY, *loc. cit.*, Vol. I, Chapter XVIII.

A REPLY TO THE NOTE OF PROFESSORS PRIGOGINE AND VAN RYSSELBERGHE.

BY

J. L. FINCK.[4]

My comments here would be about the same as those I have made with regard to classic thermodynamics in general. There is a weakness in the logical structure of our present theory (1, 3). To show this, let us consider briefly how classic thermodynamics is developed.

The basis rests on the law of conservation of energy and the Kelvin-Planck and Clausius principles, all of which derive their validity solely from experience. The first law yields the energy concept, and for a system E is defined by the statement that $dE = dQ - dW$. Both dQ and dW are measurable quantities, so that dE can be determined; this law is valid without any considerations as to whether the process is reversible or not.

For the second law from which entropy S is derived, use is made of Carnot cycle, or Carathéodory's method may be employed. This cycle presupposes the possible existence of states of "equilibrium" and proc-

[4] The J. L. Finck Laboratories, Brooklyn, N. Y.

esses which may be carried out "reversibly." This cycle is formed of isothermal and adiabatic processes represented in a two-dimensional plane, and with the aid of either the Kelvin-Planck or Clausius principle one shows that a function S exists which has potential characteristics for a reversible process.

The difficulties in the logic of this theory lie in the limited definition of the terms "equilibrium" and "reversibility." I have shown (3) that on their interpretation rest the entire foundation and possible development of the thermodynamic theory. First, in order to realize a state of equilibrium and a process which is reversible it must be assured that we have the entire number of independent variables, n, which controls the system completely. If we control a number less than n we can never be certain whether or not equilibrium has been attained and whether or not a process is reversible. Applying this argument to a closed single-phase system we must consider the possibility of having n independent variables, without restricting this number to 2 at the very outset, as is actually done in classic thermodynamics. I have shown (1, 2) that experiment justifies us in this case to take $n > 2$. But here are the difficulties we encounter; for, if $n > 2$ for a closed single-phase system I have shown (3) that we cannot draw a Carnot cycle or a similar closed cycle, and we cannot proceed with the usual analysis from which the entropy concept is derived. Carathéodory's analysis requires but one non-configuration coordinate, and I have shown (4) that this breaks down when more such coordinates are required to describe the system.

A characteristic of the weak logic is shown in Duhem's proof that a closed system in equilibrium has only 2 independent variables. In the proof as given by Prigogine and Defay (5) the number of conditions which such a system must satisfy when in equilibrium are enumerated. Among these conditions are those which state that Gibbs' chemical potential function must be the same in all phases for each chemical constitutent. However, the chemical potential function involves S either directly or indirectly (6), and the use of this quantity invalidates Duhem's proof for it is a circulatory argument in that the determination of the number of independent variables must logically precede the proof of the existence of the quantity S.

Judging from the comments by Prigogine and Van Rysselberghe, they do not appear to have recognized the fact that when I examine the existence of S for a 3-variable system I am considering the system to be in equilibrium over a given region of the 3-dimensional space, and that changes in these independent variables do not involve irreversible processes (3, p. 202). In their case, even though they consider the possibility of using ξ as a third variable, equilibrium to them is defined by only two independent variables.

Suppose we follow their argument and assume that we can carry out a process which is controlled by p, T, ξ, but which will in general be

irreversible, or, as they state, where the condition $A(p, T, \xi) = 0$ does not necessarily apply. Also, we shall according to them assume dS to form an exact differential in the extended (p, T, ξ) space. We can then follow a closed cycle in this space and arrive at the result that $\oint dS = 0$ even though irreversible processes are involved. This would be a violation of the second law from their standpoint, for classic thermodynamics requires $\int dS > 0$ for any irreversible path. There is clearly an inconsistency in their basic assumptions.

In Eq. 3 they define dS in a special way. If, instead of using S, they used some general symbol W and wrote

$$dW = \frac{dQ + Ad\xi}{T} = \frac{dE + pdV + Ad\xi}{T},$$

then, if their Eqs. 9 to 13 were valid we would conclude that W is a potential function in the (p, T, ξ) space. This is not surprising; I have found functions similar to W that have potential characteristics in the (p, T, ξ) space (see **3**, Eqs. 29 to 31). However, the function W is not the entropy function used in classic thermodynamics.

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(6) I. PRIGOGINE AND R. DEFAY, *Ibid*, p. 61.

TWO REMARKS CONCERNING DR. FINCK'S REPLY.

BY

I. PRIGOGINE AND P. VAN RYSSELBERGHE.

We shall restrict ourselves to two brief remarks concerning Dr. Finck's reply to our previous note. Other points raised by Dr. Finck are fully answered in a number of classical thermodynamic writings.

1. The hypotheses upon which the proof of Duhem's theorem is based are exactly the same as those used in the derivation of the phase rule and, in a still more general manner, in all the theorems concerning the thermodynamic equilibrium of systems of several constituents. Among these hypotheses one obviously finds that of the existence of the various thermodynamic functions of such systems. The existence of these functions cannot be demonstrated *a priori* by thermodynamics itself, but can be easily justified by statistical mechanics, as was done by Gibbs in his classical work.

2. The contradiction mentioned at the end of Dr. Finck's "Reply" does not exist.

Let us recall that in De Donder's method one has

$$dS = \frac{dQ}{T} + \frac{Ad\xi}{T}, \tag{1}$$

with

$$Ad\xi > 0. \tag{2}$$

If we consider a system undergoing an adiabatic transformation we have

$$dQ = 0, \tag{3}$$

and (1) then reduces to

$$dS = \frac{Ad\xi}{T} > 0. \tag{4}$$

This inequality expresses the classical fact that entropy cannot decrease in an isolated system. It shows, moreover, that it is impossible for such a system to describe a closed cycle because the inequality (4) would cease being satisfied along a portion of the cycle. From the fact that entropy must, outside of equilibrium, be considered as a function of at least three variables, for instance p, T, and ξ, Finck concludes that it should be possible to make the system describe a closed cycle for which one would have $\oint dS = 0$. This is an error because the inequality (2) excludes, at least for an isolated system, any possibility of a closed cycle. No contradiction whatsoever between the classical result $\int dS > 0$ (for an isolated system) and De Donder's method could possibly exist. On the contrary, this latter method consists of giving a precise definition of the cause of irreversibility by assigning it to the physical chemical transformations occurring in the system.

A RESPONSE TO THE REMARKS OF PROFESSORS PRIGOGINE AND VAN RYSSELBERGHE.

BY

J. L. FINCK.

Their first remark is practically an admission that the fundamental theorems of classic thermodynamics are based on implicit assumptions that thermodynamic potential functions involving entropy exist. That is exactly where the weakness in the logic lies, and has been treated in my papers referred to above.

Statistical mechanics cannot be cited as a justification for the validity of the existence of a thermodynamic potential function S. Statistical mechanics is based primarily on the Hamiltonian equations and

leaves out phenomena such as radiation, and therefore is a very restricted study of the more general phenomena covered by thermodynamics. Besides, the concepts of temperature, entropy, etc., have originally been derived through thermodynamics and enter statistical mechanics only by analogy. If there is a weakness in the logic of the fundamentals of classic thermodynamics, there will be at least the same weakness in statistical mechanics.

In their second remark, I believe that Professors Prigogine and Van Rysselberghe prove the point which I made that S is not a thermodynamic potential function in the three dimensional space (p, T, ξ). If S were such a potential function then $\oint dS = 0$ would hold over a closed path in this space where there are no singularities. We assume, of course, that physically no singularities exist.

FINAL STATEMENT.

BY

I. PRIGOGINE AND P. VAN RYSSELBERGHE.

We shall not pursue this discussion beyond the present brief statement.

Removal of the confusion, apparent in Dr. Finck's response, between real transformations and fictitious ones (for instance a closed path in the p, T, ξ space for which one would have $\oint dS = 0$) might be helped by an examination of Defay and Prigogine's comparison (1) of De Donder's method with that of Schottky, Ulich and Wagner (2, 3), unless the work of the latter authors is as unfavorably judged by Dr. Finck as that of Duhem, Carathéodory, De Donder, etc.

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Floating Powerhouse (*Electrical Engineering*, Vol. 68, No. 3).—Westinghouse Electric Corporation, East Pittsburgh, Pa., has announced the completion of a floating powerhouse designed to carry electric power into water-covered regions such as Lake Maricaibo, Venezuela, to help extract oil. The powerhouse will provide power for the world's largest marine-type Diesel-electric drilling rig, mounted on a barge 70 ft. wide by 175 ft. long. Three 400-kw. d-c. generators are utilized to make up the main power plant and supply all the electricity needed for drilling purposes. Four 75-kw. auxiliary generators supply power for lighting and other auxiliary loads. The electric motors for the drilling rig have a combined rating of 2,600 horsepower. Included are three 500-hp. motors for pumping the mud, lubricating the drilling bit, and carrying cuttings to the surface; one 800-hp. hoist motor; and one 300-hp. motor for rotating the bit. There is also one 60-hp. motor for powering the mud-mixing pump.

One-Way Television Antenna Improves Reception in Fringe Areas Between Co-Channel Stations.—Like a traffic policeman in a one-way street, a new television antenna has been developed which will receive signals from only one direction at a time and will greatly improve reception of set owners in fringe areas which lie between stations on the same channel.

Development of the antenna was reported recently by O. M. Woodward, Jr., research engineer of RCA Laboratories, Princeton, N. J. Consisting of an array of four 8-ft. dipoles in the form of a square, with the opposite members 8 ft. apart, the direction from which the antenna receives can be changed by flipping a switch placed near the receiver. Interconnection of the dipoles through a duplexing network makes this one-way effect possible.

The Woodward antenna is not an answer to any and all antenna difficulties, it was emphasized, but is designed to cut down co-channel interference when the receiver is located between two stations and on the fringe of their transmission areas and to reduce interference of adjacent channel stations where the receiver is insufficiently selective.

Interference experienced in Princeton between Channel 2 stations in New York and Baltimore and between Channel 4 transmitters in New York and Washington has been largely eliminated by the new array.

Many antennas now in use are not equally effective in receiving signals on the low frequency band, 54 to 88 megacycles, and the higher frequency band, 174 to 216 megacycles. Unless the low and high-band stations happen to be ideally located in relation to the receiver, conventional antennas represent no better than a compromise and will not operate with complete satisfaction on all channels.

Efficient reception on high and low bands is achieved with the new device, by attaching open-wire "V's" to each leg of the four dipoles. This, in effect, "shortens" the dipole, which is designed for low frequency reception, and permits optimum reception of high frequency signals.

NOTES FROM THE NATIONAL BUREAU OF STANDARDS.*

PERFORMANCE OF SPACE HEATERS IN A TEST BUNGALOW.

An investigation of the performance of space heaters (heating stoves, as distinguished from cooking stoves) has been completed by the Building Technology Division of the National Bureau of Standards. The Bureau's tests were conducted in a four-room Test Bungalow completely surrounded by an insulated enclosure so that the temperature might be varied to simulate any condition throughout the United States.

Two coal-fired radiant space heaters of the magazine type were chosen for the Bureau's temperature distribution tests. A third specimen was a coal heater of the surface-fired type with a cast-iron jacket. Data were also obtained on commercial models of a gas-fired and an oil-fired space heater.

The investigation established the following general conclusions:

(1) The maximum total temperature differences in the living zone (the space between 2 and 60 in. above the floor) of a house produced by a space heater are almost directly proportional to the heat output.

(2) The radius of the zone of comfort decreases as the outside temperature decreases.

(3) Houses with insulation in the walls or with storm windows and weatherstripping would have a lower heat loss per unit area than the test bungalow. They could, therefore, be warmed at a lower outside temperature without exceeding a given temperature difference in the living zone.

In producing temperature distributions approaching uniformity among the several rooms of the test bungalow, the devices tested fall into the following order of decreasing merit:

(a) Jacketed heater at approximate center of house.
(b) Radiant heater at approximate center of house.
(c) Jacketed heater in living room.
(d) Radiant heater in living room.

The Bureau tests in general show that a radiant heater, in any of the four positions described, produces slightly lower temperature differences between the 2- and 60-in. levels than a jacketed heater; and when located near the center of the house, produces a given temperature condition in the living zone with 15 to 20 per cent less heat output than a jacketed heater. A double-walled heater jacket is more effective than

* Communicated by the Director.

any of the single jackets in reducing the temperature difference between rooms in the test bungalow. For single jackets, the width of the air space does not materially affect the temperature distribution for widths from 2½ to 6 in.

In addition, the variation in size and height of space heaters used for heating residences has a slight effect on the temperature in the room containing the heater but no significant effect on the temperatures in other rooms of the house. The use of open transoms over doorways connecting adjacent rooms augments the flow of heat to the colder room, although the effect becomes increasingly less at the lower levels in the colder room.

The investigation also showed that the heat distribution in the house could be improved by the use of a desk fan placed to receive warmed air from the heater and blow it toward the door or an opening to another room. This effect varies with such factors as the size and power of the fan, and its proximity to the heater. In fact, results of earlier space heater tests, using integral fans, have indicated that the unattached fan is as effective as the integral fan in improving the distribution of heat.

STANDARD FREQUENCY BROADCASTS FROM HAWAII.

A new experimental radio station on the island of Maui, Territory of Hawaii, is now broadcasting continuous time and frequency standards. This is station WWVH, operated by the National Bureau of Standards to provide the Pacific area with four useful technical services: standard radio frequencies, time announcements, standard time intervals, and standard musical pitch. Omnidirectional antennas radiate approximately 400 watts of power on each carrier frequency.

The broadcast services of WWVH are essentially the same as those of station WWV, operated by the Bureau at Beltsville, Md., which transmits on frequencies of 2.5, 5, 10, 15, 20, 25, 30, and 35 Mc.

It is expected that station WWVH may be usefully received at many locations not served by station WWV, and that simultaneous reception of WWV and WWVH in some localities will not interfere with ordinary use of the standard frequencies and time signals.

During the continuous operation of WWVH on 5, 10, and 15 megacycles, accurate time signals in the form of audiofrequency pulses are transmitted on each carrier frequency at intervals of precisely one second; on the 59th second of each minute the pulse is omitted. Standard musical pitch is provided by modulating each carrier at a standard audio-frequency of 440 cycles per second (A above middle C). The audio frequency, starting precisely at the beginning of each hour, is broadcast for four minutes and interruped for one minute; this sequence is repeated throughout the hour. Greenwich Mean Time is given in

International Morse Code every five minutes; time announcements refer to the time when the audio tone returns. The station call letters WWVH follow each time announcement.

The radio and audio frequencies and time intervals of one minute or longer broadcast by WWVH are accurate to one part in fifty million or better. Time signals are precisely adjusted with U. S. Naval Observatory time so that they accurately mark the hours and shorter intervals. Seconds pulses from WWVH are synchronized to within 0.001 second with those sent out by WWV.

CORROSION TESTS OF IRON AND STEEL PIPES.

A continuous-flow ten-year laboratory test on the corrosion resistance of commercial pipe materials has been completed at the National Bureau of Standards.

Tap water of known analysis was circulated at constant velocity through a system of eight vertical columns, each made up of 14 specimens of pipe lengths. The specimens consisted of two types of cast iron, three of wrought iron, two of ingot iron, and three of open-hearth steel. Individual specimens were removed and replaced with new ones of the same materials at the end of specified periods ranging up to 10 years. Corrosion of the exposed pipe, as indicated by loss of weight and depth of pits, was then evaluated in relation to duration of exposure.

Studies of the data indicate that while there were significant differences in the corrosion of some of the materials, the more expensive pipes offer no appreciable advantage in this respect over the usual cast-iron water pipe.

The results of the tests indicated that there was no great difference in the rates of corrosion of most of the wrought materials when measured either by loss of weight of by depth of pitting. A low-alloy steel had the highest corrosion rate while a copper-molybdenum ingot iron and a nickel-bearing wrought iron had the lowest rates. Other low-alloy materials such as wrought irons, ingot iron, and ordinary medium carbon steel pipes corroded at intermediate rates. A rough estimate of the minimum life of these bare materials when subject to continuous flow of Washington, D. C. water would be about 15 years on the basis of this work.

IMPREGNATION OF LEATHER WITH ELASTOMERS AND SYNTHETIC RESINS.

Resin treatments that promise to effectively improve the wear resistance of sole leather have recently been developed at the National Bureau of Standards.

In addition to increasing the abrasion resistance, the use of synthetic resins should reduce the amount of tanning materials now required to produce high-quality leather. The success of the resin treatments,

coupled with the knowledge gained in their development, suggested the possibility of a similar leather treatment using rubber.

Three laboratory methods were developed for treating leather with resins. The first immersed the leather specimens in monomer which is subsequently polymerized *in situ;* the second method immersed leather in polymer solutions, which may or may not be elastomers; while the third immersed the leather in a partially polymerized liquid which is further polymerized in the leather itself.

Abrasion resistance is improved approximately 75 per cent for vegetable-tanned crust leather impregnated with *n*-butyl methacrylate monomer, followed by polymerization *in situ*. The abrasive resistance of the untreated crust leather was approximately the same as that of sole leather. Treatment of vegetable-tanned crust leather with solutions of Castilloa rubber improves abrasion resistance about 50 per cent, while treatment with Thiokol LP-2 improves resistance about 30 per cent. However, treatment of vegetable-tanned crust leather with polybutyl methacrylate solution-polymer showed no improvement in abrasion resistance.

Half-hour static water absorption tests reveal a reduction of one-tenth to one-third the amount of water absorbed by untreated leather, depending upon the kind of leather and treatment. Water vapor permeability of treated shoe upper leather is higher than similar leather containing 20 per cent grease.

Preliminary research with rubber solutions has shown that, by proper choice of processing methods, as much as 20 per cent of rubber can be deposited within unfinished vegetable-tanned leather. The process may be satisfactorily applied to several different types of leather. Dynamic, or wet-flex, water absorption and water transmission of sole leather as well as abrasion resistance are all improved about 50 per cent by rubber treatments. Solutions of natural rubbers having 40 per cent or more of rubber are prepared from cold milled rubbers and conventional solvents. The impregnated rubber may be vulcanized in place by the use of an ultra accelerator of the dithiocarbamate type.

NEW INTERNATIONAL TEMPERATURE SCALE.

On January 1, 1949, the National Bureau of Standards began using the definitions of the International Temperature Scale of 1948 both in its own research program and in calibrating instruments for other scientific and industrial purposes. Based on a draft prepared by members of the Bureau staff, the new scale was adopted at Paris by the Ninth General Conference on Weights and Measures in October 1948. This is the first revision of the International Temperature Scale since its adoption in 1927.

The experimental procedures by which the scale is to be realized are substantially unchanged; but certain refinements, based upon experience, have been incorporated to make the scale more uniform and reproducible.

Two revisions in the 1927 definitions of the scale result in appreciable changes in the numerical values assigned to measured temperatures. One of these is the change in the value for the silver point from 960.5° to 960.8° C., which affects temperatures measured with the standard thermocouple. Thus, in the range between 630° and 1063° C., numerical values of temperature are higher than on the 1927 scale, the maximum difference being about 0.4 degree near 800° C. The adoption of a new value (1.438 cm.-deg.) for the constant c_2 in the radiation formulas changes all temperatures above the gold point. In the new scale, Planck's radiation formula is specified instead of Wien's for calculating temperatures above the gold point as observed with an optical pyrometer. Since Planck's law is consistent with the thermodynamic scale even at high temperatures, this change removes the upper limit to the scale formerly imposed by the use of Wien's law.

There are several other important modifications in the scale which cause little or no change in numerical values for temperatures, but serve to make the temperatures more definite and reproducible. For example, the standard platinum resistance thermometer is to be used as a reference instrument from the oxygen point to the freezing point of antimony (about 630° C.), rather than over the range from −190° to +660° C. Platinum of higher purity is also specified for the standard resistance thermometer and standard thermocouple, and smaller permissible limits are given for the electromotive force of the standard thermocouple at the gold point.

BUILDING CODES AND CONSTRUCTION IN THE UNITED STATES.

The housing shortage in the United States has focused attention on two problems relating to building codes: first, the present status of building codes and, second, the relation of existing codes to the rate of construction.

The present status of building codes has been studied by the Building Technology Division of the National Bureau of Standards. The Division maintains an index of municipalities with populations of 2,500 and over, records the dates of local building codes in effect, and compiles other information concerning building regulation. Recently, a survey was undertaken to provide a check on the information at hand and to furnish more complete coverage. The facts disclosed by the survey confirm the general impression that a considerable number of codes have not had a major overhauling for some time. When arranged according to the dates attributed to them by local authorities, codes now in effect can be classified into the following six groups in Table I:

TABLE I.—*Age of Dated Codes.*

Age Group	Number of Cities	Percentage
Up to 5 years	574	27
6 to 10 years	366	17
11 to 15 years	244	11
16 to 20 years	377	18
21 to 25 years	327	15
Over 25 years	264	12
Total	2,152	100

Some difference of interpretation is possible in the table above. A code may be assigned a date as of the time it was officially adopted and yet be more modern than this date would indicate because of the effect of the number of amendments. On the other hand, a code of rather ancient vintage may often be reissued with a recent date on its cover, perhaps indicating a deliberate reaffirmation of the old requirements but more probably representing a reprinting without critical re-examination.

The fact that amendments have been added does not necessarily mean that the codes have been actually brought up-to-date. First, most amendments tend to be minor. Second, even major amendments usually do not achieve the results attainable by complete and total revision. Third, designers and builders have difficulty in determining what is actually required in a code where numerous amendments have been superimposed on it.

It is significant that 29 per cent of the municipalities have no type of building regulations. Some municipalities do not have codes but do have rudimentary ordinances requiring permits in order to do building or setting geographical limits within which some types of combustible construction may not be erected. Others make use of state regulations. Information of this kind is summarized in Table II, which follows:

TABLE II.—*Data on Municipalities with Codes or Dated Codes.*

Code Information	Number of Municipalities
1. No Code	990
2. Permit Ordinance	183
3. Fire Limits Ordinance	164
4. State Regulations Adopted	37
5. No Code Age Given	47
6. No Report on Code Status	67

The absence of codes in such municipalities suggests that in these areas new materials, construction methods, and designs may be used. On the other hand, the absence of codes represents a real hazard to the public safety and often to the economic interest of property owners.

Data for the entire country show that 71 per cent of municipalities have some sort of regulation. In certain states all municipalities of

2,500 population or over have some form of building regulation; in others practically all are covered; in still others coverage drops well below half.

Many states have miscellaneous legislation applying to certain buildings throughout the state, and others have state building codes. The fact that a municipality does not have a code does not necessarily mean that it is altogether without building regulation.

Response to the question whether revision was going on or contemplated provides an indication of the concern of local governments about bringing the codes up-to-date. The replies are summarized in the following Table III.

TABLE III.—*Prospective Code Changes.*

Kind	Number of Cities
1. Revising	213
2. Planning Revision	32
3. Drafting Code	50
4. Contemplating Code	9

The status of present building codes requires careful consideration in view of the disparity in age, type and scope of regulations, and various local factors. Most codes are, in varying ways, out-of-date, nearly one-third of the municipalities lack proper regulations, and some codes are not rigorous enough, raising the question of the public safety. Revision of old codes is complicated by at least two factors: (1) Testing and evaluation problems involved in the appraisal of new materials and developments for revision of codes are many and complex, and exceed the facilities of municipalities. (2) Diversity of geographic and climatic conditions necessarily requires variations in the detailed regulations of codes. However, greater uniformity in codes is feasible, and such uniformity would achieve economies in construction and simplify the problems of designers, builders, and manufacturers.

Delays in code revision are partly due to lack of standard methods of testing and evaluating new developments in materials, methods, and design. Local authorities engaged in building-code revision have a number of sources of information to which they can turn: Organizations of building officials, fire underwriters' associations, and standardization bodies, as well as the National Bureau of Standards and other Government agencies. The dissemination of technical information by such organizations represents an important element contributing to the application of new developments in the construction field and to the maintenance of proper safety measures.

Investigations of the Bureau, extending over a period of nearly 50 years, cover the entire field of building technology. Data relating to properties of materials, whether acquired as a part of the building technology program or in the other programs of the Bureau, are compiled and integrated for this purpose. The importance of such syn-

thesis stems from the fact that thousands of materials and products are utilized in construction.

There is some danger that the effect of codes on the current rate of construction may be overemphasized, and this danger is a very real one in a period in which the housing shortage is acute. The cost of housing is determined above all by the cost of materials and labor, but another element enters the situation: American concepts of what constitutes adequate housing have changed in the direction of demanding more expensive housing.

In many cases research contributes to lower costs; on the other hand research developments increase the number of problems faced by building code officials. Where a large variety of new materials and methods is involved, the magnitude of testing and evaluation problems is formidable. For this reason the Bureau has not only pursued a vigorous program of research, but of testing and developing methods of evaluation as well.

One of the factors apt to be slighted in considering housing research is the inter-relationship with research in the whole construction field and in fields apparently completely divorced from housing. For years the investigations of approximately one hundred sections of the Bureau in physics, chemistry, engineering, and mathematics have produced valuable results which were desired initially for purposes other than construction but which were invaluable in the building technology program.

Further and more extensive work in research, test methods, testing and evaluation and modernization of codes is clearly needed.

THE FRANKLIN INSTITUTE.

STATED MONTHLY MEETING AND 125TH ANNIVERSARY OF THE FOUNDING OF THE FRANKLIN INSTITUTE HELD APRIL 20, 1949.

The monthly meeting of The Franklin Institute was held on April 20, 1949, in the Lecture Hall of the Institute in conjunction with the celebration of the 125th Anniversary of the Founding of The Franklin Institute and the 200th Anniversary of Franklin's Electrical Experiments.

The meeting convened at 8:15 and was called to order by the President, Mr. Richard T. Nalle, who extended the Institute's welcome to all in attendance. He also extended sincere thanks on behalf of the Board of Managers to the organizations who furnished special exhibits in our Museum for the Anniversary occasion. They were the Electrical Association of Philadelphia, the United States Navy, and the Bell Telephone Company of Pennsylvania. The President acknowledged with thanks the efforts of all members of the Board of Managers and the Institute staff members who had contributed time and labor to make this celebration a memorable one.

The President asked the Secretary, Dr. H. B. Allen, to announce the gifts recently received by the Institute.

The first gift, a picture by the Association of Prisoners of War of Verdun, was presented through the good efforts of Miss Florence Sibley, who had been interned in Verdun by the Germans during the last war. Miss Sibley, a member of the Institute and an officer of the French Legion of Honor, was called upon to say a few words. She explained the symbolic picture which represented France's liberation by American tanks in the first world war. This picture came to America on the French "Merci" train and was displayed during the meeting. Miss Sibley expressed the delight of the Association of Prisoners of War of Verdun that the picture was so well received by The Franklin Institute and hoped it would act as an "emblem in the relationship between our countries."

The second gift, Benjamin Franklin's Will of 1757, was presented to the Institute by Mrs. Mary Curtis Zimbalist in honor of her father. The Secretary called upon Mrs. Zimbalist for formal presentation of the Will.

Mrs. Zimbalist described the circumstances under which it became possible to procure the original holographic will of Benjamin Franklin and said that upon reading the last paragraph of it, she was so impressed by the spiritual thoughts expressed in it that she could not resist purchasing it. Knowing her father's real appreciation and interest in Dr. Franklin and in The Franklin Institute, Mrs. Zimbalist felt it a privilege to present it to the Institute.

The Honorable George Wharton Pepper was asked to accept officially the Will on behalf of The Franklin Institute. Mr. Pepper graciously accepted this gift in a talk that brought delight to all his listeners. His remarks will be later published in the JOURNAL.

Mr. James H. Robins, President of The American Pulley Company and a member of the Board of Managers, was the speaker of the evening, presenting a paper on "The Story of The Franklin Institute." This interesting and informative talk will be published in full in a later issue of the JOURNAL, as will the entire proceedings of the meeting.

HENRY B. ALLEN,
Secretary.

MEMBERSHIP.

ACTIVE MEMBERS ELECTED AT THE MEETING OF THE BOARD OF MANAGERS, APRIL 20, 1949.

ACTIVE FAMILY.

Harvey Bartle, Jr., M.D.
Harry L. Decker
Harry L. Dickerson
Harry S. Goldstein
Kube Krisch, M.D.
C. H. Schwertner
Louis J. Warbeck
Edwin E. Wieck, M.D.

ACTIVE.

Francis M. Bellarmino, M.D.
Thomas C. Braber
Nathaniel H. Copeland, M.D.
J. Philip Evans
G. Thomas Holloway
J. Thomas Krall, M.D.
Irving H. Leopold, M.D.
George D. Marshall, Jr., M.D.
Robert Marshall, M.D.
Ralph C. Matsinger
Vincent P. McDevitt
James J. McKnight
J. Frank Rehfuss
Gerard Sheehan
Ronald S. Shissler
Irving Woldow, M.D.
Walter M. Wyman

ACTIVE NON-RESIDENT.

W. A. Casler
Bertrand Japikse
Clarence A. Lovell
Domina Eberle Spencer

NECROLOGY.

Price Wetherill Janeway, Jr., '44
A. Atwater Kent, '17
Dr. Thomas S. Stewart, '75

MUSEUM.

From the day of its inception The Franklin Institute has been concerned with the technical education of youth. In the beginning of its activities efforts were concentrated upon furnishing the elementary education which could not be obtained elsewhere by classes under competent teachers. Then, as local authorities assumed responsibility for technical studies, the Institute restricted its provisions to the more advanced studies until these, too, were embraced by the curricula of the colleges and public schools.

For a while it looked as though the Institute had been deprived of all means by which it could aid and encourage an aspiring youth, but it was only pausing to seek new occasions. The opportunity was seized to promote one of the greatest experiments in the field of education which had been attempted in this country. This was realized in the great scientific and technical museum, now a prominent feature of Institute activity. In addition to its function as an agency in adult education, the museum has played a major role as an adjunct to the schools' visual education programs.

The museum is dynamic. The visitor's participation in the operation of the exhibits is invited, and this has helped greatly in contributing to the cultivation of a personal interest in the museum by visitors. The further development of these personal relations has been a matter of considerable concern to the members of the museum staff, who have tirelessly sought to expand them. An interesting development achieved by the Museum Education Department with the co-operation of the *Philadelphia Inquirer* is the organization of an annual Science Fair. The first of these Fairs will open on May 21st and will continue until the 29th. With the purpose of promoting an early and continuing interest in science study, exhibits have been invited from students varying from kindergarten to senior high school. All students within an area embracing the eight neighboring counties are eligible to exhibit. Gold, silver, and bronze medals will be awarded the winners in graded divisions entering exhibits in basic physical sciences, applied physical sciences, physiographical sciences, and biological sciences. Each exhibitor will be awarded a certificate of acceptance.

Science Fairs have been held in other parts of the country and they have proved to be a source of stimulation and encouragement to young students through the provision of a wider

audience for their accomplishments. The *Philadelphia Inquirer* and The Franklin Institute are combining in the task of securing for local students a wider appreciation of their work because it is fully realized that pure science is the life blood of industrial progress and it must secure recruits. There never was a time in the history of the world when the need for scientists was greater than it is today, and these Science Fairs have been found an admirable means of encouraging young people to adopt science as a profession.

The Fair is only a modern version of the several methods which the Institute has improvised for the encouragement of young people to extend their studies beyond the prescribed limits of the school classroom. These methods have changed with the passage of the years but their abiding purpose is unchanged. The promotion of the Fair in Philadelphia has been enthusiastically supported by the teachers in the area, and their enthusiasm for the project has given the joint-sponsors assurance that this, the newest, effort of the Institute to encourage youth and to furnish a link with the general public and with industry will be not less effective than those past efforts which brought universal commendation.

JOURNAL OF THE FRANKLIN INSTITUTE.

The following papers are to appear in the JOURNAL within the next few months:

MICHELMAN, JOSEPH: Analysis of a Varnish Used by Stradivarius.
COHEN, GERALD H.: Operational Approach to Non-Linear Circuit Analysis.
COURT, ARNOLD: Refractive Temperature.
THOMSON, WILLIAM T.: Deflection of Beams by the Operational Method.
DEJUHASZ, K. J.: Graphical Analysis of Impact Bars Stressed Above the Elastic Range.
SCANLAN, R. H.: A Note on Analysis of Beam-Columns under Arbitrary Lateral Load and End Restraint.
MINORSKY, N.: Energy Fluctuations in a van der Poel Oscillator.
MARIN, JOSEPH: Stress-Strain Relations in the Plastic Range for Biaxial Stresses.
WILLIAMS, W. A.: History of Power Transmission.

LIBRARY.

The Committee on Library desires to add to the collections any technical works that members would wish to contribute. Contributions will be gratefully acknowledged and placed in the library. Duplicates received will be transferred to other libraries as gifts of the donor.

Photostat Service. Photostat prints of any material in the collections can be supplied on request. The average cost for a print 9 × 14 inches is thirty-five cents.

The Library and reading room are open on Mondays, Tuesdays, Fridays, and Saturdays from 9 A.M. until 5 P.M., and Wednesdays and Thursdays from 2 P.M. until 10 P.M.

On and after June 1, the Library hours will be 9 A.M. until 5 P.M. on Mondays, Tuesdays, Wednesdays and Fridays; 2 P.M. until 10 P.M. on Thursdays; and 9 A.M. until 12 noon on Saturdays.

RECENT ADDITIONS.

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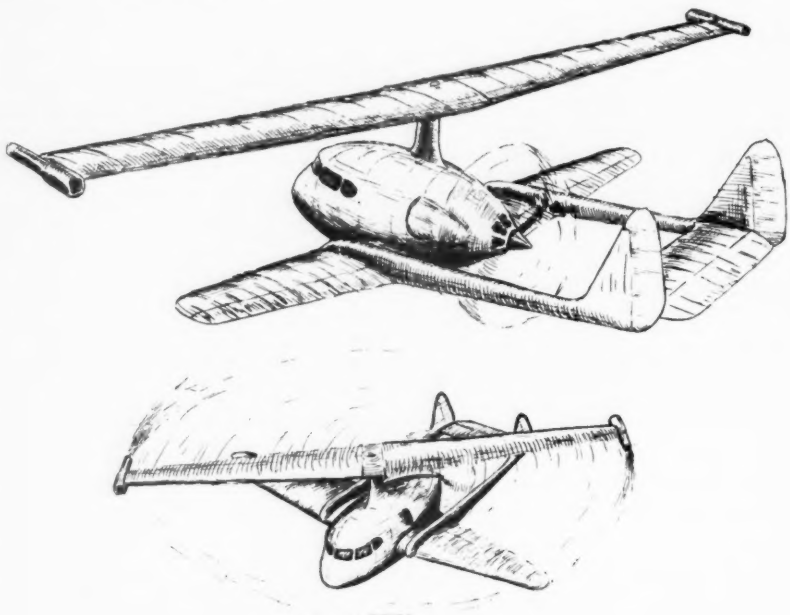
THE FRANKLIN INSTITUTE LABORATORIES FOR RESEARCH AND DEVELOPMENT.

Abstract of **Convertible Aircraft,—A Statement and Discussion of the Problem.**[1]—R. S. BARNABY, S. M. BERKOWITZ, AND W. H. COLCORD.[2] Convertible aircraft are aircraft in which the essential features of the airplane and the helicopter are combined in the hope of providing in one craft the high speed, stability, maneuverability, and fuel economy of the former with vertical ascent and descent, slow speed, and hovering ability of the latter. Such craft may be divided into two general classes.



Proposed Herrick Convertoplane.
Drawing by R. S. Barnaby.

[1] Paper presented before Annual Meeting of the Institute of Aeronautical Sciences, New York City, 24 January, 1949, by R. S. Barnaby, S. M. Berkowitz, and W. H. Colcord. Published in *Aeronautical Engineering Review*, April 1949.

[2] Messrs. Barnaby, Berkowitz, and Colcord are all Research Engineers, Aeronautics Section, The Franklin Institute Laboratories for Research and Development, Philadelphia 3, Penna.

In the first class are craft in which the rotor axis remains substantially vertical and in which, by stopping the rotating wing, the craft may be converted from helicopter to conventional airplane. The proposed Herrick Convertoplane, shown in the accompanying illustration, falls into this class.

In the second class are those craft wherein the rotor axes shift from vertical to horizontal, the rotors for direct-lift helicopter flight becoming propellers for conventional airplane flight.

The problems involved in the various proposed types are discussed and certain general parameters established for evaluating the practicability of the several types.

The need for research and test in numerous problems involved in the successful development of such craft is stressed, it being the firm belief of the authors that such research, though long and expensive, is apt to be considerably cheaper in both time and money than futile attempts at solving the given problem without it.

BOOK REVIEWS.

MICROWAVE ANTENNA THEORY AND DESIGN, edited by Samuel Silver. 623 pages, 16 × 23 cm., drawings and photographs. New York, McGraw-Hill Book Co., Inc., 1949. Price, $8.00.

It is suspected that Volume 12 of the M. I. T. Radiation Laboratory Series was somewhat late in being published because the authors undertook an almost impossible task, namely, the inclusion of all major microwave antenna work done in this country and in Great Britain. At any rate, the book was eagerly awaited by microwave specialists for many months.

So much effort was expended in the various laboratories in attempting to develop a logical procedure for microwave antenna design, which in general requires empirical treatment, that the amount of knowledge so derived could not be compressed into a single 600 page volume. The book does a great service, however, by providing solutions for fundamental antenna development problems.

The volume begins by pointing out that the microwave region to be treated (wavelength, 0.1 to 25 cm.) is located at a transitional point in the electromagnetic spectrum between the ordinary radio and the optical regions. Certain concepts and techniques from both of these are applicable to microwave antenna design.

The next step is to show how distributed circuit elements whose dimensions are comparable to the wavelength may be replaced by suitable lumped impedance elements which are a transcendental function of frequency rather than an algebraic function. Certain network theorems which are made usable by this means are then presented.

The mathematical relations for radiation from current distributions are developed next employing a rigorous analysis in terms of the vector fields according to J. A. Stratton's "Electromagnetic Theory." This section is intended primarily as a guide to the design of antenna feeds.

The geometrical theory of wavefronts and rays is introduced as soon as the concept of energy flow has been established in terms of radiation fields from sources. The geometrical approach does not explain the phenomena of scattering and diffraction which underlie the formation of antenna patterns by reflectors and lenses. Therefore, it becomes necessary to revert to the superposition of fields to determine the effect of a conducting obstacle.

With the foregoing as a theoretical background the specific design problems of aperture illumination and the properties of different types of feeds for directional antennas are presented. The emphasis is on deriving mathematical expressions to describe the secondary pattern characteristics produced by various types of aperture distributions.

The succeeding chapters, comprising more than half of the volume, are devoted to specific procedures in design. Construction details of feeds, linear-arrays, horns, dielectric and metal-plate lenses and beam shaping devices are dimensioned in terms of wavelength. The concluding chapters of the book are devoted to antenna measurements from the standpoint of techniques as well as equipment.

The reader will recognize numerous designs borrowed from actual radar systems and used as examples. These may often help the designer to compare salient properties of the different types of antennas based upon their measured characteristics and to select the appropriate solution to his own problem.

Using the methods of analysis given in this book together with the empirical data and curves it should be possible for the design engineer to produce a practical and efficient microwave antenna for most applications.

C. W. HARGENS.

THE OPTICAL PRINCIPLES OF THE DIFFRACTION OF X-RAYS, by R. W. James. 623 pages, 14 × 23 cm., illustrations, plates. London, G. Bell & Sons, 1948. Price, $17.50.

This book is Volume II of the series "The Crystalline State." Its field of specialization, as given by the title, is the fundamentals of the interaction of X-rays with matter. The succeeding volumes of the series will deal with other specific aspects of the field of X-ray diffrac-

tion. Professor James' contribution to the subject during a period of more than two decades uniquely qualified him to write this definitive work. The treatment appears to meet the needs both of experienced workers, who will appreciate the organization and discussion of this large amount of material, and of newcomers into the field of X-rays, who will find this book pedagogically excellent. It is this latter characteristic mainly that accounts for its length, but this reader, for one, is grateful for the opportunity to be led so thoughtfully, albeit slowly, through this type of subject matter. Examination of any topic in the book makes it apparent that Professor James has given great care to organization, illustration, and reference. The book is, then, a unique combination that will make it a much used reader and reference in a fundamental field of modern physics written by a man prominent in its development.

The book begins with the geometrical aspects of diffraction, utilizing reciprocal lattice concepts, and considers effects of lattice variations upon intensities. Then the entire subject of intensities of reflections is discussed, closing with Ewald's dynamical theory. A chapter on the atomic scattering factor follows, which includes a discussion of calculation methods. Then follow sections on anomalous scatter and temperature effects, containing thorough discussion of experimental tests of the several theories. A complete chapter is given to experiments dealing with the intensity formulae. The chapter on Fourier methods is brief, as this subject has been treated elsewhere and will be the subject of a later volume in this series. Laue's dynamical theory is the subject of a chapter. An intensive treatment of the scattering of X-rays by non-crystalline matter and by small crystals occupies the last quarter of the book.

JOSEPH SINGER.

QUANTUM MECHANICS, by Leonard I. Schiff. 404 pages, 16 × 23 cm., illustrations. New York, McGraw-Hill Book Co., Inc., 1949. Price, $5.50.

It gives this reviewer extreme pleasure to write about this new book by Dr. Schiff because the writer has profited by attending the course in quantum physics given by the author at the University of Pennsylvania in 1941, at a time when this work was the basis for that graduate course. The text material is written much in the same style that the subject matter was presented in the classroom, but there is no evidence of the stilted form which is sometimes evident in formal classroom lectures.

As the author indicates, the volume has a three-fold purpose: to explain the physical concepts of quantum mechanics; to describe the mathematical formalism; and to present illustrative examples of both the ideas and the methods. These goals are achieved primarily through the use of analytical methods, with sufficient mathematical rigor to satisfy most mathematical physicists.

This book is definitely not a work for an undergraduate physics course. The text is intended for use at graduate level and as a reference book for persons who are reasonably familiar with atomic structure, classical mechanics, differential equations, electromagnetic theory, and the special theory of relativity. This background is necessary, as can be seen from an examination of the scope and content of the book, which can be roughly divided into three parts. The subject of quantum mechanics, the physical basis for these concepts, and the formalism of the Schrödinger wave equations are first considered. The mathematical developments are prefaced by a discussion of the experimental background and the ideas of the old quantum theory. This serves as groundwork for the formal presentation of the Schrödinger equation applied to the non-relativistic motion of a particle in a force field, with considerable attention being given to the physical interpretation of the solutions.

The next section, comprising the greatest part of the work, presents solutions of the wave equations, applied to the usual problems considered in the typical one-year graduate course in quantum physics. Starting with the three physical postulates which help in the interpretation of the wave functions, they are applied to the problem of single particle motion, then to: the exact solutions of the wave equation for energy-level and collision problems; the Heisenberg matrix theory; approximation methods for stationary and time dependent problems, such as perturbation theories, the Born, variation, WKB, adiabatic and sudden approximations; and a semi-classical treatment of radiation theory, atoms, molecules, and nuclei.

An introduction to advanced quantum mechanics, consisting of chapters devoted to the relativistic wave equations, the quantization of wave fields, and quantum electrodynamics closes the volume.

Numerous problems are included at the close of each chapter which illustrate or amplify the text material. The many original research papers referred to throughout the book serve as further references for the serious reader.

S. CHARP.

ISOTOPIC CARBON, by Melvin Calvin and others. 376 pages, 15 × 24 cm., illustrations. New York, John Wiley & Sons, Inc.; London, Chapman & Hall; 1949. Price, $5.50.

With the advent of the uranium pile and its neutron flux of a hitherto unavailable magnitude, radioactive elements became obtainable in quantities and at prices satisfactory to most demands. Carbon, the basic element of organic chemistry, and a *sine qua non* of animate matter, was soon being produced as a radioactive isotope of mass 14 and as rapidly employed wherever tracer work involving carbon compounds was being pursued. Concomitant with these effects, the literature dealing with the synthesis and use of isotopic carbon compounds has grown tremendously and created a definite need for an up-to-date laboratory manual for chemists employing C^{14} or C^{11}.

Isotopic Carbon, written to satisfy this need, presents first an applicable presentation of the techniques necessary and extant today for tracer research with radioactive carbon. Second, it gives detailed directions for all isotopic carbon syntheses obtainable and considered important by the authors.

After a brief discussion of the nuclear properties and radiation characteristics of C^{14} and C^{11}, and the use of C^{11}, the authors present an informative and practicable description of the instruments available today for the counting and detection, in the gaseous, liquid or solid phase, of the emanations of radioactive carbon. There is sufficient detail to enable most experimenters to reach some conclusion concerning their own needs. The problem of preparing samples for counting with these instruments is well covered with a wide variety of methods gleaned from all sources available to the authors.

The directions for performing the syntheses of C^{14} compounds are in practically all cases sufficiently detailed and lucid, and arranged in a logical manner. In general, the preparations are intended for employment of the small quantities (for example, 2 to 10 millimoles) necessary to obtain products of optimum specific activity and economy. However, large enough quantities are entailed by some of these preparations, that they may be considered as only part of the realm of regular organic syntheses. This section of the book includes an interesting chapter of biosyntheses.

The appendices include a short exposition on the statistical interpretation of counting data, and various bits of information of interest to the radiochemist.

This book or manual, a pioneer in its specific field, should be extremely valuable to any chemist employing radioactive carbon. It accomplishes its purpose and serves as a new rallying point for the great era of radioactivity that has now begun.

ALBERT L. MYERSON.

ELECTROMAGNETIC WAVES AND LIGHT, First Part, by Charles F. Meyer. 83 pages, 14 × 22 cm., drawings, tables and illustrations. Michigan, Edwards Brothers, Inc., 1948. No price (paper).

This book is to be highly recommended as an analysis in a qualitative nature of the principles of electromagnetic waves and in the interpretation of some of the physical properties of light. The principles involved are presented from the experimental rather than the theoretical point of view. The author tells the story behind the wave equations without presenting these equations. Had the author extended the text to include Maxwell's equations and solved them with the necessary boundary conditions about which the description centers, this would have been a very powerful piece of work.

However, the text develops descriptively in an elementary logical fashion the origin and properties of electromagnetic waves and the experimental evidence of such with emphasis on propagation, polarization, time and space variations. More detailed study is made of polarization, particularly circular and elliptical polarization. Also spectral results are analyzed. There are included various charts or electromagnetic spectra and particular analysis of radio, X-rays, and gamma rays.

ALECK GOLDBERG.

ELEMENTS OF MECHANICAL VIBRATION, by C. R. Freborg and Emory N. Kemler. Second edition, 227 pages, 15 × 24 cm., illustrations and tables. New York, John Wiley & Sons, Inc., 1949. Price, $3.75.

The problems of vibration analysis which occur in many branches of engineering are the subjects of this new elementary, undergraduate-level textbook, now in its second edition. This is no work greatly dependent upon higher mathematics; rather, it is presented in as simple a manner as possible from an engineering point of view. The elementary phases of this subject are covered in a form which allows immediate application to a variety of practical problems. The number of engineering problems which can be and are solved by an elementary approach is surprisingly large, and for these, the simpler forms of differential equations are developed and solutions obtained. Typical of a general class of common problems are those pertaining to vibration analysis and elimination, and the determination of natural frequencies for many different types of systems.

The approach which the authors have continued in this edition is that of stressing the basic analysis of vibration problems, then following the theoretical development with illustrative problems worked out with detailed explanations of the physical phenomena. In many cases, these sections are followed by others devoted to a review of the methods and formulas which can be applied to other related problems with a minimum of complication and further reference to either this texbook or to some of the more complete treatises on the subject of mechanical vibration.

This second edition has ten chapters, two more than in the previous one. A short introduction includes a discussion of important definitions and symbols and units. The practical problems chosen as examples throughout the book require the use of the commonly used engineering units, and to this end the authors have chosen the inch-pound-second system as a standard. This chapter is followed by those which consider single degree of freedom vibrations with and without damping, and free and forced vibrations. Of interest is the wide variety of simple engineering examples pertaining to: the manometer; the pendulum; the disk and shaft; the torsional pendulum; and others. The large number of problems is sufficient justification for the amount of space devoted to them.

The broader field of vibrating systems with several degrees of freedom, being a more complex phase, has only one chapter devoted to it, the discussion being centered primarily upon the analytical solution of some common cases of several degrees of freedom, with illustrations for tabulation and graphical methods of obtaining solutions to problems of this type.

The remainder of the book is devoted almost entirely to problems of engineering application, the chapters having emphasis upon: vibration isolation and absorption; beams; sound; mechanical and electrical models of vibration systems and equivalent systems; and the mobility method of solving vibration problems first introduced by Firestone in 1938.

A wide variety of problems useful for class room and home study are included in each chapter, the answers to many of which the authors have thoughtfully included.

S. CHARP.

AN INTRODUCTION TO TEXTILE BLEACHING, by J. T. Marsh. 512 pages, 14 × 22 cm., illustrations, plates. New York, John Wiley & Sons, Inc., 1949. Price, $6.50.

Contrary to its title, this book covers much more than the limited subject of textile bleaching, and its scope is much broader because of the necessity of informing the student of

many of the basic chemical and physical characteristics of various textile fibers before explaining the methods of scouring, bleaching and drying connected with their purification and manufacture. This broad coverage and thorough explanation of each phase of the subject is in sharp contrast to the methods used in the era before the first decade of this century when the closely guarded secrets of the successful father were handed down to his son. This work demonstrates the importance of a thorough scientific knowledge of every phase of a subject before attempting to explain it to students, the author showing by his multitudinous references how much study and research has been put into this book.

The subject matter opens with a fundamental outline of the occurrence and properties of the various textile fibers, their relative chemical constitution and physical structure, their molecular arrangement, together with many photomicrographs, to complete the actual picture of the fibers, both synthetic and natural. The second part covers wetting agents for reducing surface tension and detergents for emulsifying. The actual scouring and bleaching of cellulosic fibers is explained in part three, while the comparable treatment for animal fibers is given in part four dealing principally with wool and silk. Various processes now in use are described, their chemistry explained and pictures shown of the machinery available for performing these operations. Part five describes the processes and machinery for drying textiles, while part six explains the various types of damage tests currently applied for evaluating the condition of various fibers before or after treatment.

While the stated aim of this book is to help the younger technologists just entering the textile industry, many older and more experienced workers in this field might read this book with considerable profit. It has a wealth of specialized information that should make it desirable as a reference work for both chemists and engineers, and as a record of the present state of the art.

F. R. SIMPSON.

ENGINEERING METALS AND THEIR ALLOYS, by C. H. Samans. 913 pages, 16 × 24 cm., illustrations, tables. New York, The Macmillan Company, 1949. Price, $7.50.

Engineers, metallurgists, and all users of the metallic materials should be interested in this new text book which gives a background of metallurgy in addition to a wealth of other information. The large size of the book is a result of its encyclopedic nature. While only a limited treatment is made of many of the subjects, the vast amount of material makes this book ideal for use as a text in a survey course devoted to the engineering metals. In combination with other outside reading material, and the selection of certain chapters, class room emphasis may be placed on certain specialized phases of the broad field of metallurgy.

Being a survey work, not much new and original matter is presented, but there are included many charts, tables and diagrams, as well as an unusually large number of photomicrographs, the products of some of the best workers in the field.

As the title of the work indicates, interest is in the engineering metals, those important basic metals which, for economic reasons or because they possess unique properties, are used in great quantities and predominate in a majority of the commercial alloys. Eight metals fall into this category, namely: copper, iron, lead, tin, aluminum, magnesium, nickel, and zinc. While other metals are of engineering importance, they are so primarily because they may serve as the bases of special alloys or are present in commercial alloys where they determine the important properties of these alloys.

The production of the engineering metals from their ores is described in detail in four chapters of the twenty in the book. The metals magnesium, aluminum and zinc are chemically active and extreme care must be taken in the reduction of these metals from their ores. Pig iron, the first product of the iron blast furnace, is less active chemically, and the methods for its reduction are radically different. Still different in the method of production are the metals copper, nickel, lead and tin, these being obtained by pyrometallurgical or electrolytic means. Most of the current commercial methods for producing all the engineering metals are described with sketches, diagrams and flow charts supplementing the clearly written text.

The general and physical characteristics of the metallic engineering materials in their pure states, and the theory of alloys, primarily the binary type, are considered. Then follow chapters devoted to: the principles of heat treatment; the shaping and forming of metallic materials; corrosion; special alloys resistant to water and chemical corrosion, wear and abrasion, and those for applications requiring high strength and toughness and other special properties; and tool and bearing alloys.

It is felt that this work, while not perhaps written in extreme detail for the specialist with some particular interest in the field of metallurgy, is so broad in scope that it may answer most questions raised by the non-specialist regarding the production of metals, their applications, and their machining and special properties. The many references to other books and to the periodical literature greatly increase the value of this text. It should be a reference work in all engineering libraries and experimental laboratories, in addition to fulfilling the needs of mechanical design engineers.

S. CHARP.

FLUID DYNAMICS, by Victor L. Streeter. 263 pages, 15 × 23 cm., drawings. New York, McGraw-Hill Book Co., Inc., 1948. Price, $5.00.

This text carries out its purpose of introducing the basic theory of fluid flow and the application of the theory to specific problems. Each chapter is designed to give the reader the definitions of the subject matter, the theoretical background, a step-by-step mathematical development of the physical concepts, and exercises for applying the theory. Emphasis is placed on explaining the mathematics of the derivations since it is assumed that the reader has had only elementary calculus.

Beginning with the basic fluid-flow concepts, theorems, and definitions, the author presents the classical theory of frictionless fluid flow. both for the two- and three-dimensional cases, examples of the theory (and the graphical representation thereof) applied to specific body shapes, and finally deals with the subjects of vortex motion, viscous flow, and boundary-layer conditions. Some of the specific theorems and equations presented include: the Blasius theorem for flow around a cylinder which leads to flow around an airfoil and the graphical method of developing a Joukowski airfoil; the Schwartz-Christoffel theorem for transforming flow about a polygon into uniform flow parallel to a real axis; the Navier-Stokes equations for viscous flow; and the equations for boundary layer conditions.

This volume should be welcomed by students of fluid flow for its clarity of style; however, due to the detail of the presentation of the subject matter, it is not recommended as a quick reference for those only vaguely acquainted with the field.

LISBETH CROWELL.

VELOCITY-MODULATED THERMIONIC TUBES, by A. H. W. Beck. 180 pages, 15 × 22 cm., drawings and tables. New York, The Macmillan Company; Cambridge, The University Press; 1948. Price, $3.75.

The rapid advances in radio techniques, particularly with regard to the development of ultra-high frequency radio which were made during the war and in the short period thereafter, are the subjects of the new "Modern Radio Technique" series of monographs now being published. This particular volume was written by one who was personally responsible for important advances in the field of velocity-modulated thermionic tubes, as a Scientific Officer for the British Admiralty.

In the late 1930's the Varian brothers, Hahn and Metcalf, and Haeff almost simultaneously published their first papers reporting the development of devices which combined the principles of thermionic tubes and the electromagnetic theory. These tubes were respectively named the klystron, velocity-modulated tube, and inductive output amplifier, or in general, velocity-modulated thermionic tubes. While these devices have been the subject of several books published in this country, the treatment given in the subject volume is somewhat different. Here is found a general introduction to velocity-modulated tubes and their mode of operation

in a form readily understood by one with a reasonably adequate knowledge of pre-1939 radio technique.

The klystron is a particularly interesting device with which to study the interaction of high frequency fields with electron beams for the various functions are separated out in the velocity-modulated tube so that study can be made of the effects of variation of a single parameter.

The velocity-modulated principles are introduced with consideration of the two resonator klystron as an amplifier and oscillator, with emphasis on the physical picture of its operation. This is most clearly explained with sketches of the amplifier and a discussion of the Applegate diagram, which relates the distance from the center of the buncher gap as a function of time, illustrating the process of electron bunching. The author then proceeds to consider qualitatively the operation of the two resonator tubes as a self-oscillator; then he extends the velocity-modulated principles as they apply to the reflex klystron, the Heil tube, and the now obsolete inductive output and Hahn-Metcalf tubes.

The cavity resonator, which plays such an important part in the klystron, is considered in detail, since it is the means for the introduction of the electromagnetic field. The theory of resonators can be approached from two points of view: as a generalized transmission line or as a vibrating mechanical system. This latter point of view is used in this book, the oscillating nature of the electromagnetic field being introduced as a next step to a vibrating acoustic system. Maxwell's equations in free space, written in the form of generalized coordinates, serve as a starting point for the determination of the TE and TM modes of vibration for various cavities. Typical of the regular shaped resonators considered are: the rectangular box; the circular cylinder with a central post; the rectangular section toroid with capacitance loading; and the coaxial line resonator. For each of these there are derived the vibration modes and some estimate of the losses calculated by several approximate methods.

Having thus introduced the subject, the mathematical theory of velocity modulation and electron dynamics is derived from Maxwell's equations, as well as a theory which is capable of predicting the output power and available conversion efficiency. The cases of small signal theory and large signal conditions are separately considered.

Principles developed in the earlier chapters are then applied to: velocity-modulation amplifiers; frequency multipliers; klystron oscillators; and reflex klystron oscillators. The general theory developed is capable of predicting the operating efficiencies well within engineering approximation. Closing chapters are devoted to a discussion of miscellaneous types of velocity-modulation tubes, the limitations and defects in V.M. tubes and their design requirements and manufacture.

In essence, it can be said that the major part of this work is the general theory of the interchange of energy between the electromagnetic field and the electron beam, together with the application of the theory to various types of velocity-modulated tubes. Not written in textbook form, the volume is, however, a good account of developments in this field of research, with many references to the most important papers. The book should serve as a good reference work for electrical engineers and physicists interested in the interaction of electromagnetic waves and electron beams.

S. CHARP.

SYMPOSIUM ON INTERNAL STRESSES IN METALS AND ALLOYS, organized by The Institute of Metals. 485 pages, 14 × 22 cm., drawings, illustrations and tables. London, The Institute of Metals, 1948. Price, 42s.

This book contains the papers that were presented in the Symposium on Internal Stresses in Metals and Alloys organized by the Institute of Metals and held in London, in October, 1947. The papers are grouped into three sections: Section I—Measurement of Internal Stresses; Section II—The Origin, Control and Removal of Internal Stresses; and Section III—Effects Associated with Internal Stresses.

Various methods of measuring internal stress are discussed in the papers in Section I. Such are mechanical methods applicable to cylinders, thin-walled tubes, flat plates and bars; physical methods such as measuring the magnetic properties, electrical resistivity and internal friction of metals; and X-ray methods.

Section II of the Symposium commences with the classification and nomenclature of various internal stresses. Descriptions of the origins of internal stresses from plastic deformation, from chemical or structural changes, or from the fact that parts of a material may have different coefficients of thermal expansion are given. This is followed by papers on specific cases of the existence of internal stresses in steel castings, in steel cooling from the austenitic regions, in electro-deposited metals, due to welding, produced by the sliding of metals, in turbine rotors, in beams after bending and in glassware. The concluding papers discuss the relief of internal stresses by cold-working, by heat treating and by shot-peening (a method of cold-working); and the deliberate inducing of internal, or residual, stress to produce greater usefulness of material, as in the pre-stressing of helical springs and autofrettage of gun tubes.

Section III is divided into two parts: (a) Effects on a Microscopic and Sub-Microscopic Scale, containing nine papers, and (b) Effects on a Macroscopic Scale, containing six papers. Some of the papers are of a general nature and some of a particular nature. For instance, the opening paper in part (a) endeavors to derive a formula to determine the limit at which a metal undergoing shear changes from the elastic to the plastic zone, and appears to be practically successful from empirical observations of some cold-worked, pure metals. On the other hand, another paper in part (a) discusses the effect of cold work on the rate of precipitation in aluminum-7 per cent magnesium and aluminum-8 per cent magnesium-1 per cent zinc alloys. There is a fine paper on the phenomenon of age-hardening, wherein a brief history of the theories of age-hardening advanced during the past 26 years is presented. Microscopic stresses are formed within the lattice structure during hardening which must affect the behavior of the metal during testing, particularly during stress-corrosion and creep tests. Other papers in this part discuss internal stresses arising from transformations in metals and alloys, the effect of internal stresses on rates of transformation in iron-nickel alloys, diffusion and precipitation in alloys, internal stresses due to anistropic, thermal expansion of pure metals and alloys, and a photo-elastic approach to stress modifications caused by inhomogeneities.

The first two papers in part (b) of Section III discuss the phenomenon of stress-corrosion, how the chemical behavior of a metal affects the chemical behavior. It is shown in certain instances that shot-peening, by protecting the metal from chemical action of surrounding media, is beneficial. It is known, also, that shot-peening, by producing a residual stress counter to the applied stress, definitely augments the fatigue life of a metal. The second paper discusses the stress-corrosion in such of the common industrial metals and alloys as copper, aluminum and magnesium alloys, lead, nickel and nickel alloys, mild steel and the chromium-nickel austenitic steels. The mechanism of stress-corrosion cracking is explained, including the functions of stress and the corrosive medium and the propagation of cracks.

A short paper on stress-corrosion cracking of steels in the presence of sulfur compounds discusses several experiments conducted to illustrate the unfavorable effects of sulfur compounds on the fatigue life of certain steels. There is a paper discussing the various internal stresses in railway materials presenting specific examples and showing, in some cases, how internal stress is used advantageously to increase fatigue life. The concluding two papers discuss delayed cracking in hardened alloy steel plates and hard-zone cracking in welded alloy steels.

The last hundred pages of the book are devoted to discussions of the papers by men prominent in the various fields of study, thereby affording the reader several views of the particular subject and consequently providing him with a broader knowledge of each. There are extensive bibliographies at the end of the majority of the papers, some containing more than seventy, so that merely as a reference volume the book is valuable.

E. W. HAMMER, JR.

MEASUREMENT OF STRESS AND STRAIN IN SOLIDS, The Institute of Physics. 114 pages, 16 × 24 cm., illustrations. London, the Institute of Physics, 1948. Price, $4.00.

The book herein reported is based upon the papers presented at a conference held by the Institute of Physics in July 1946, the subject chosen being the study and measurement of stress and strain. So much work has been done in this field of physical measurement in the

past ten years that entirely new techniques involving several branches of physics had to be developed.

Electric resistance strain gages and photo-elastic study of model structures have been developed to such an extent that at the present time these aids in the study of stress and strain distribution in solids are used for most large and many small structures, especially those which undergo dynamic stresses, such as airplanes, ships, and other pieces of motive equipment.

The twelve papers and summaries which were presented at the Conference are here collected; they present a rather accurate picture of the principal practical methods now available. Three survey papers are concerned with: electric strain gages; recent developments in photo-elasticity; and other methods for the measurement of strain, such as extensometers and brittle lacquer coatings.

The first of these discusses the physical characteristics of the wire resistance strain gage, presenting much pertinent information such as: the behavior of the gage under strain; the behavior of the matrix or gage backing and its adhesive layer; the effects of imperfect sticking, incomplete polymerization of the adhesive, changing humidity and temperature, and electrical and mechanical characteristics which limit the current carrying capacity and mechanical stress.

The second survey paper reports upon the important developments in photo-elasticity between 1938 and 1946, with special emphasis on the use of synthetic resins, the measurement of stress in three dimensions, and methods for the separation of principal stresses in plane photo-elasticity. The third short paper summarizes the use of various types of extensometers.

The remainder of the papers extend the scope of the three fields mentioned above with reference to specific examples, designs, and uses. In the field of resistance gages three papers discuss: the use of gages in combination for component load measurement; high frequency strain gages; and a note on the application of resistance strain gages in shipboard measurements. Photo-elasticity techniques with models, the use of X-rays in strain measurements, acoustic strain gages, and associated electric circuit details are the subjects of the other papers.

The authoritative manner in which the material is presented and the clearly written and edited text help to make this collection of technical papers a useful addition to libraries of mechanical engineers, instrument designers, and stress analysts.

S. CHARP.

SILICONES AND OTHER ORGANIC SILICON COMPOUNDS, by Howard W. Post. 230 pages, 15 × 23 cm. New York, Reinhold Publishing Corp., 1949. Price, $5.00.

The publication of a new book in a rapidly advancing field of chemistry is always a matter of great interest and it is a bitter disappointment when its quality is not of the best. It is all the more discouraging to the reviewer who is placed in the difficult position of being fair to both the scientists interested in the field and to the author who has laboured to be of aid to his fellow workers. This book poses just that problem. The author does not state clearly the purpose of the book, and it is necessary, therefore, to consider the structure of the book and whether there exists a need which this book will fill rather than how adequately the author has dealt with his problem.

The book is loosely arranged into chapters under the headings: 1. Introduction, 2. Halogenated Silanes, 3. The Work of Frederick S. Kipping and Others, 4. Organic Compounds of Silicon Prepared at Moderate Temperatures (Journal Literature), 5. Organic Compounds of Silicon Prepared at Moderate Temperatures (Patent Literature), 6. Organic Compounds of Silicon Prepared at Higher Temperatures, 7. The Uses of Polymerized Oxosilanes, 8. Silico-Organic Compounds Analogous to Ethers and Amines, 9. Nomenclature, and 10. Physical Properties. In Chapters 2 through 8 which comprise the meat of the book, each chapter consists of short paragraphs devoted to a single reference or to a few related references. The appearance is that of a card file of notes strung together in roughly chronological order, references which are closely related often appearing several pages apart and separated by unrelated material. The critical comment is meager and often misleading, and no attempt is made to present an orderly structure among the references which would help the reader, and expose flaws or gaps in our existing knowledge of these interesting materials. Although the

uses of organosilicon compounds are discussed, the physical chemistry of these materials is almost completely ignored. The chapter on nomenclature is adequate and consists for the most part of quotations from the article by Sauer, and the report of the American Chemical Society's Nomenclature Committee on rules for the naming of silicon compounds. It is unfortunate that these rules have been so consistently violated in the text. The table of physical constants includes values of melting point, boiling point, density, and refractive index for most known organosilicon compounds and is the most useful feature of the book.

This book may be of value to workers in the field who want in one place an extensive bibliography with some comment on each reference. It may be helpful to those who wish to know about the various uses of silicone materials, although the chapter on this topic has a confused organization. It will be useful for its list of physical constants of individual compounds.

The book will be confusing to the average chemist with no previous knowledge of the field, and it is likely to be of little value to students or to non-chemists.

The statements by the publisher on the dust jacket that this book "critically evaluates all the vast amount of work done in this unusual and little understood department of organic chemistry," and that it is the "first critical summary of the subject," are both unwarranted and unfair to the author who makes no such claims.

ARTHUR E. NEWKIRK.

BOOK NOTES.

MATHEMATICS, OUR GREAT HERITAGE. Essays on the Nature and Cultural Significance of Mathematics. Selected and edited by William L. Schaaf. 291 pages, 14 × 21 cm. New York, Harper & Brothers, 1948. Price, $3.50.

These essays have been collected for the thoughtful reader who would understand why mathematics is of much importance to mankind. Grouped in five sections, the essays treat of mathematics from the following viewpoints: its role as a creative art; its origin and development; its internal structure and intrinsic nature; its relation to science and technology; and its cultural and humanistic bearing. The sixteen authors include some of the most outstanding writers on mathematical and scientific topics, such as E. T. Bell, G. H. Hardy, George Sarton and T. Dantzig.

ENGINEERING THE NEW AGE, by John J. O'Neill. 320 pages, 14 × 21 cm. New York, Ives Washburn, 1949. Price, $3.50.

A veteran science reporter, Mr. O'Neill, in this volume, presents some thoughts on how man can make the earth a better place in which to live. He sees the need for a development of social consciousness by science and engineering with a resulting new approach to the world's problems. The treatment is interwoven with facts from various sciences.

Gallium (*The Foundry*, Vol. 77, No. 3).—Gallium, a rare, silvery-white metal of unique properties, now is being produced and sold by Aluminum Co. of America. Metal is liquid at 86 F. but will not boil until heated to around 3700 F. Its density (5.9) is about that of aluminum, but only half that of metallic mercury, which is liquid at room temperature. Gallium shows a strong tendency to undercool, and the liquid metal may be held for some time at temperatures almost as low as the freezing point of water without solidification taking place. Like water, but unlike most elements, the density of gallium is greater as a liquid than as a solid; gallium actually expands on solidifying. Gallium wets glass and porcelain, and when heated as high as 1000 F. a globule of the metal will remain bright and shiny due to a protective natural oxied film which forms on the surface.

Industrial Integrator.—A new industrial integrator, Model 808, for continuous sensitive integration of electrical quantities has been announced by the Weston Electrical Instrument Corporation. The integrator, designed for use in general industrial and research applications, provides means for simple and effective integration of d-c. potentials or currents with respect to time.

Fundamental elements of the integrator are the Weston Model 806 Integrating Relay, an electronic relay circuit with associated sealed reed type relays, and a counting mechanism. The Model 806 is the primary element, operating the relay circuit to initiate an oscillatory action, the frequency of which is proportional to the input. The counter totalizes the number of cycles, to provide a running time-integral of the input.

The unusual sensitivity of the Model 808 Integrator makes it ideal for the following applications:

1. Light integration (using a photronic photoelectric cell) totalizing the amount of light—daylight, arc light, ultra-violet, infra-red—on paint test samples, fabrics, plants and other objects.
2. D-c. ampere-hour integration from low potential shunts—permitting accurate checking of efficiency in the production of aluminum, magnesium, etc., and in electro-chemical process industries.
3. Watt-hour integration using thermal converters—for power integration at higher frequencies as in induction heating. Also for integration of power of several systems totalized by use of thermal converters.
4. Total radiation integration using thermopiles—ideal for agricultural and botanical surveys for totalizing the amount of all radiations from sunlight.
5. Integration of nuclear radiation—in combination with Geiger counters or ionization chambers for totalizing the radiation from radioisotopes or X-rays.
6. Integration of quantities measured by changes in transmitted light—such as the totalization of opaque particles suspended in liquids flowing through pipes at a constant rate.

The unit is chassis mounted and enclosed in a cast aluminum weatherproof case. Unlimited service life may be expected, according to the manufacturer, with routine vacuum tube replacements only at about 2,000 service hour intervals.

NOTES FROM THE BIOCHEMICAL RESEARCH FOUNDATION.

Cooperation in Research.—ELLICE MCDONALD, Director. One of the most significant happenings in the last fifty years has been the increase in the *scale of operations*. This invades every phase of human endeavor in the more advanced centers of civilization. War itself has developed from the comparatively small professional or semi-professional armies to the employment of masses involving all the people of a country, either in the armed forces or in employment pertinent to warlike purposes. In this country and in the war just over, not only were the armed forces involved, but everyone in the whole country was doing "war work" for the production of warlike material for the maintenance of the army by producing food or by other efforts and occupations which aimed at the aid and comfort of the military, so that these could do their work better, more quickly and more easily in order that the enemy might be defeated and peace return.

This could not be possible without the huge aggregations of capital in corporate arrangement which were available for the Government to call to their uses. Where would the huge army be supplied if there were not available such great industrial units as the Ford Motor, General Motors, the du Pont Company, the oil companies, and many others.

Organization is the key and this has occurred through the efforts of exceptional men and the accumulation of capital. But the exceptional men did it and created the enormous organizations. Of course they could not have done it unless the time was right. They had the special qualities required at the right time. They had the enterprise, the drive, and the judgment. They created fortunes many times that of the greatest fortunes of the revolutionary period such as those of Stephen Girard and General George Washington. It is a matter of *increase of size of operations*. But as in every successful organization, it required the advent of the exceptional man.

An expression of enlarged effort is the increase in horsepower. A strong man can exert only about one sixth of a horsepower in sustained effort. Yet the United States in peacetime produced 15 horsepower for every man, woman and child in the country, not counting automobiles which produced as much more. The total product of manufacturing corresponds to the amount of mechanical power employed. Wages taken as an expression of enlarged effort have increased in a regular ratio and always in this country correspond to the amount of horsepower developed. In the United States and Great Britain wages and horsepower rise together in direct proportion; in Italy, a backward nation,

wages are only twenty per cent compared to the amount of horsepower. The war was one of horsepower, faster aeroplanes, better tanks, increased mechanical transportation, better oil and gasoline, and that made the army more fully effectual because of *increase in size of operations.*

Extension of research does not depend upon horsepower, but upon the extension of powers of research by means of new tools which extend the capacity of research workers exactly as increase in horsepower has increased the scope and capacity of industrial organizations. These tools, the microscope, electrical instruments, the thermionic tube, the electrophoretic apparatus, the cyclotron, spectroscopes, and many others increase the scope of man's senses and make measurements possible to record. Quantitative measurements make exact findings and exact findings make confirmation of results available, so that progression of further research is possible. But this is only one factor in the large scope of research and group organization. It requires, in addition, the facilities and opportunity which greater funds make possible. The vast accumulation of printed and recorded experiments in the literature is another example of the enlarged scope of operations. This gives a background of accumulated experience that has never before existed. This enlarges the research man's sphere of knowledge so that he may know what has been done by others, their methods of arriving at their conclusions and avoid pitfalls as well as to draw conclusions so that his own experimentation may not be a duplication but useful. This accumulation of printed experience is large and increasing every year. In the Biochemical Research Foundation, outside of books and periodicals, there are 37,000 scientific reprints or papers, classified as to subject, author, and subclassified as to methods. This is the most valuable single scientific aid in the laboratories, for it is in itself a phase of enlargement of man's powers so as to increase the scale of operations. It is possible to survey all phases of a problem before beginning the work, to eliminate the unessential and to choose the proper path for the great adventure of research. No amount of application or energy can overcome false direction. "It is no use running on the wrong road."

With the opportunity comes the man who has the vision and does the spade work just as the opportunity in industrial affairs evolved the exceptional men who expanded organization from small beginnings to great ones as has been done by the big business corporations. These drew into their service men adaptable to such group effort, trained younger ones and developed others. Then there becomes a group, all inspired with the idea of getting better work done by helping each other to do it and themselves gaining more reward thereby.

It may be that we are only re-discovering the possibility of working together which we call cooperation. Elton Mayo has suggested that in

previous times when life was simpler and people more dependent upon each other as in a village each did his work in relation to the others and cooperated for the general good. The smith worked with the carpenter and the husbandman with the artificer. However this may be, cooperation and coordination in a scientific group must be learned and, in some cases, it must be compelled. The great social revolutions which have cut across the historic continuity of Western civilization are a special form of change. The compelling motives, according to Thomas, are of four elemental kinds: (1) the wish for new experience, (2) the wish for security, (3) the wish for recognition and (4) the wish for response. The desire for security is opposed to the desire for new experience and the desire for security implies avoidance of danger and death and implies caution and conservatism. In this, it is opposed to the adventure and new experience which is inherent in scientific research. This incompatability makes organization in research more difficult.

The art of good management is to create an organization which will develop to its highest point the initiative of individuals, consistent with an orderly progression and cohesiveness of purpose. Management is an art, not a science. Hence its forms express the color and personality of one man, the director or chief. Through his choices, his example, and his instructions, the chief creates an extension of himself throughout the organization. From this, it follows that there is no royal road to building a good organization. Each organization must be built for the specific purpose in hand and its form is dependent upon the ability and characteristics of the persons who compose it.

The purpose of management and the collective intelligence, experience and imagination which implies direction to a given scientific task in research is to expand the power of each individual worker to be useful. Through organization large numbers of scientists are enabled to pool their efforts for the general purpose of doing better work.

As a result of past experiences, the scientific method has in the experimental method the most powerful intellectual tool in man's possession. It is based upon the principle of controlling experimental conditions to the end that only selected factors are allowed to vary. With cooperative organization the scientific method gains its fullest fruition.

In the past times it was the individual genius, the "prima donna" type of worker who by his qualitative observations developed new paths of knowledge. The examples held up by those who resent efforts of organization of research always begin with Faraday and Pasteur. They argue that, if these succeeded by working alone in a cellar or a garret, no more is now needed and that workers should be allowed to isolate themselves in and apart from their fellows. But it must be remembered that these two were the exceptional men, the one in a

million, and no count is taken of the thousands of ineffectual lives who spent their scientific efforts without accomplishment and so left no mark in the memory of man or on the printed page. Then too, Pasteur, at least in his successful days, had a good deal of collaboration and, no doubt, would have welcomed it in his obscurity.

These do not realize that the province of organization is to extend the value of individual capacity, to give new slants on the problems by other minds and to give the advantages of other sciences to the main problem. Separate workers rarely meet and each is a law unto himself.

They must act as if failure was impossible. They must not begin the venture timidly and when they meet with a difficulty they must not retreat from it in discouragement. THIS IS A TIME FOR COURAGE, RESOLUTION AND EFFORT. Each must find his function, perform it fully and not overstep except in emergencies. In most large efforts there must be one person as a leader whose decision is final. If the decision is against the research worker, or his suggestion, he must cooperate in the decision wholeheartedly. If he feels that a mistake has been made, he must take time to draw up the situation as he sees it and explain why he thinks a mistake has been made. To get things done every one in the group must cooperate fully and willingly and without mental reservations.

No man can do it all or know it all. This comes to be realized more and more in these days of elaboration of scientific facts and intermingling of various phases of science. This is an age of specialism and, for one example, it is important that these experts be brought into proper consultation and perspective without the domination of their specialties. A gibe about a specialist always lingers, "He knows everything about his specialty except its relative unimportance."

One rather surprising thing is the little interest research workers, much occupied in their own work, have in other phases of science. The absorption in one phase which of itself has a mass of literature and problems of its own takes so much time and concentration that it is not surprising that there is a tendency to be completely secluded in one area of science. Then too, they speak different languages and forever are revising their nomenclature. The bacteriologists at one fell swoop rebranded all their stock and gave new names to all their bacterial organisms, so that all these blossomed out with new names which require often a moment's thought to recognize the organism which was rustled from the old herd and rebranded under a new name. The physicists spring a new one every few minutes and the literature is well supplied with suggestions for improved nomenclature. Even our old friend "oxidation" has created a controversy and emerged with its face lifted by new meanings and new associations.

An example is the following paragraph:

"To use the term 'imide' as a synonym for 'peptide' and to call 'nylon' a polyimide would be correct in the language of classical organic chemistry, and would bring clarity into the relations of protein chemists and 'nylon' chemists. 'Polypeptide' could well be reserved as a term obtained by condensing amino acids and 'polyimide' for the products obtained by condensing all other carboxylic acids with organic amines.".

Perfectly correct no doubt, but it makes it difficult when a newborn term is met for the first time without previous acquaintance with the conditions of its birth, and one is inclined to ask, "whose baby is it and was it born within the bonds of Holy Matrimony? Who are its parents?"

Fourteen years ago I was asked to organize several symposia at the Institute of Chemistry which was a three weeks' meeting. The subject was "The Relation of Physics and Chemistry to Biochemistry." Thinking to do a good job, I asked two of my friends, a physicist and a chemist, to meet with me to give me advice and assistance on the project. Both have been presidents of their national societies. To my astonishment I had to act as an intermediary interpreter between these two, expert in their own sphere and who apparently knew so little of the other's *patois*, that I, who knew less about it than both of them, had to explain for them. After that meeting a question was asked me, "Has physics really added anything to the knowledge of chemistry?" This when the structure of the atom and the mechanism of electron interchange has explained so much of chemical reactions! Maybe things are better now, but it is an example of complete absorption in one aspect of science.

One important matter which has to do with the beginning of organization is the orientation of men, skilled in one phase of science, into other areas of knowledge. All science is now one. If chemical combination depends upon the giving, taking and sharing of electrons and the breath of life depends upon oxidation and reduction which is the giving and taking of electrons, surely both are related to physics whose study is the forces of the atom.

The aim of our Foundation is to attach biochemical investigation to the exact sciences of chemistry and physics. Biological research in general is upon the experiment and error basis: This type of effort is quite all right if one does enough experiments, but sometimes the number of experiments required approaches infinity. But the great difficulty in biochemical and biological research is the number of variables and the absence of criteria. One alone of these might easily be overcome, but the combination presents difficulty. In human biochemistry, all the factors which go to make up life present such a multitude of intercorrelating variables that deduction from experimentation is difficult unless the variables are connected with some phenomenon which can be quantitatively or statistically measured as in chemistry and physics.

For this reason, when a new man comes, an attempt is made to instruct him gently and gradually into the other phases of science and the apparatus for exact measurement which are in the laboratories. It is interesting to follow such education and to see active minds seize the possibilities of new areas of experimentation which are open to them.

One experience was unforgettable. A bacteriologist who was a Ph.D. and quite distinguished in his own specialty was a newcomer appointed to the department of bacteriology. Wandering in the laboratory, he came to a dark room and asked, "What are those apparatus covered with black cloths which are down in the lower dark room?" It was explained that these were a spectroscope with notched Echelon cells, a spectrophotometer and other instruments. "What are they and what do they do?" When he was instructed as to what their purpose was, he seized with avidity the possibilities of extension of his own area of experimentation and indeed asked these instruments to do many things which they were not able to do and some that they could. Then he discovered the Beams' air-driven centrifuge which can run at 3000 revolutions per second (yes, second, not minute) for sedimenting and fractionating his material, the Svedberg oil-driven centrifuge for determining particle size and the Tiselius electrophoretic apparatus for fractionation and for determination of the distribution of various proteins. With his eager and active mind, he seized on these new methods and the apparatus managed and controlled by other groups and did a considerable amount of research on lines that had not been done before, and which could not have been done in his isolated state. He got so good that a drug company offered him a large salary and he deserted us.

This orientation and education is the beginning of coordination in research. Cooperation cannot be achieved if people don't know what they are talking about. Specialization is so complete and there is so much to learn in each branch that it is no wonder that men become mentally and intellectually isolated in their own phases. My experience of 45 years in research has led me to believe that the lone worker has about three years of valuable work in which his ideas are prolific and vital: after that, unless his vision is enlarged, his imagination stimulated and his mind instructed by other phases of science, his further efforts are only elaboration of detail and continuation of modifications of the same formula of effort. This, however, is a generalization and like generalizations may or may not be true: certainly must be excepted the exceptional man, but how rare he is.

The longevity of the research desire is only to be maintained by a constant struggle against the diffusion of the specialization of its energy. If the struggle is not made, the research desire after a brief flowering succumbs into the common processes of diffused thought. Other people unconsciously fight a man's concentration whenever it diminishes his use to them. Inside of himself, it is fought by the indolence of partial

achievement and the incidence of new and extraneous interests which produce a diffusion of energy. Resting upon laurels, enjoying the rewards of partial achievement are fatal to the research effort. Motive must overcome the scattering of life's energy into little parts of less and less usable forms. Once the research desire, the intense curiosity as to the arrangement and order of existing things, is lost, it is rarely recovered. Nothing is more pathetic than a burnt-out scientist. The disillusionment of a goal attained should never affect the research worker. There are always new worlds to conquer: new adventures to try: new research gambles to take. Research is a demanding occupation: self-immolation is more or less of a necessity. It is strenuous because it involves no routine: each day is a new opportunity and perhaps a new miracle. For this reason it is often fatiguing.

No splendid isolation is possible for the scientific worker. On the contrary, it is one of the gravest dangers which besets specialists and specialists we must all be today. The man who tends to do everything will never achieve anything. If the mathematician, the chemist, the physicist, the biologist, the engineer and others lose contact with each other, their separate progress will soon come to an end. Many gaps in the uneven front of research of today are represented by unexplored fields which lie between the activities of two or more branches of science. These gaps can only be filled in by the interchange of ideas from day to day and over a long period of time, because it is difficult for scientists in different fields to learn the *patois* which each speaks. Often the lack of interest of the specialist in problems which lie aside his own domain is due to a lack of understanding of the language in which the other scientist is speaking. Mechanical-mindedness is a peril to which the scientific worker and above all the specialist is exposed even more than his fellow men. Teamwork and cooperation are the only methods of avoiding this depression and encouraging receptivity to new ideas.

The Biochemical Research Foundation started from scratch 20 years ago and has had the opportunity of not only being a research organization, but also an experiment in organization of research. We have made many mistakes: we probably will continue to make more. Correlation at first depended upon one man, the director, and at that it was thought that there was a limit to the number of scientists who could be correlated and brought together in an organization with any success. This was thought to be about forty workers in all degrees of importance. After a number of the workers had been educated and trained in cooperation (and that is necessary), it was found that more than that number could be correlated because captains could be made to act for small groups under them. Whether there is a limit to the number of workers who can be correlated in scientific work without the suppression of individuality is a question and no doubt will vary in different situations. The danger with large units is that correlation

may become stereotyped and perfunctory and so the spirit of the effort may be lost. However, there may be a size at which efficiency is at a maximum.

Then departments were set up in chemistry, physics, organic chemistry, bacteriology, cytology, physical chemistry and these captained by department heads. Correlation was then attempted by calling the department heads together and leaving it to them to employ those under them on the problem as was required. This was not so good as men with a number under them did not like to divert their workers from problems which were going forward with them.

Various kinds of reports were tried, weekly, fortnightly, and monthly, these circulated to those who might have a hand in the matter. One definite conclusion was that periodic reports should not be a burden upon the work or onerous to the worker. This should be brief and concise. Of course, at times, a full summary report is necessary to get a proper perspective of the work. These are numbered later and filed in the library so as to be available to others. Often at first new workers resent these reports as unnecessary, but after they are accustomed to them, they become reconciled as they find their copies are a good resume and diary of the progress of their work. War time interfered with such reports, but a brief one page report every few weeks is a very comforting thing to the director.

The procedure now used at the initiation of any project is to first discuss the matter most carefully with the person most involved; to have the library staff search the literature; to circulate a statement of the project to the persons who might throw some light on the project and the possibilities of new phases or difficulties. Then these are called together for discussion and this almost always brings a suggestion that certain other scientists in a different line of work might also be well added to the discussion. Not everyone in the discussion becomes involved in the project, but these become familiar with it and can continue thinking about it and often come forward with something they can do to aid the job.

Usually the one most interested is put in general charge of the project and he or one close to him is responsible for collection of the data required in the reports.

An example may be taken from a bacteriostatic and germicidal fraction which was obtained from soil bacteria. It was discovered by the microbiologists and was fractionated by those running the Beams' air-driven centrifuge. It was passed to the bacteriologists and the cytologists to determine its qualities and powers, to the microchemists for analysis, identification and determination of its probable composition, to the organic chemists for fractionation, to the spectroscopists for characterization and for the determination of the spectrographic differences between the various fractions obtained by the chemists, these

fractions to the cytologists for toxicity and other experiments on animals, to the microscopists for record of crystalline structure, to the surgeons for study of its external effects upon badly infected wounds, to the physical chemists for measurement of the physical constants and further study as to its structure. It went as we say "through the mill." All these were from our staff work and this is our common procedure.

A similar situation is a recent study of the effect of phosphatase upon desoxyribonucleic acid where the effect was shown to be linked to the degree of polymerization and molecular weight. Although only two authors appeared and it was their problem it involved eight others to include electrophoresis and the Beams high speed centrifuge, streaming birefringence, sonic vibration, microchemistry and radiation by X-rays and the cyclotron and the ultraviolet quartz microscope. In this way particle size and molecular weight were correlated to enzyme action and this experimental result would not have been possible without a complete organization with proper apparatus and trained observers for these collateral yet necessary measurements.

What chance had a lone worker on a job like this? He would have a biological fraction which he believed potent and would nurse it, hoping by trial and error to prove he had something; even for his animal experimentation he would have to call on someone else. A distinguished chemist, a past president of the American Chemical Society, had a biological fraction which he believed was potent, but was bogged down on his identification. We lent him our facilities and in a short time he was able to identify the fraction which proved to be a new vitamin. But another sad story is that of a research worker who nursed for two years a fraction he believed to be potent to find it was sodium chloride. But the inference as to the value of cooperate work is equally obvious in the first example as in the last.

No statement as to cooperation is complete without considering apparatus. These must be chosen with the idea of their mutual usefulness. A spectrographic set-up is not for the spectroscopist alone. Every department, in addition to doing its own research, must consider itself a *service* department to the others when it is called upon to do this. But it should be ruled that not everyone can plunge into one department and claim its help without full consideration and authority from the chief, for otherwise, these service departments would be swamped by inconsequent requests.

Last of all, the library should not be merely a depository of information and a collection of books and journals, giving these only on request. It should be informed as to the projects and their ramifications and a look-out should be kept for new papers on the problems or related subjects and for older papers which might have been overlooked.

Organization of research is belittled and protested against by a considerable number of scientists who feel that they will be cramped in the development of their originality and confined in their liberty. They fear being caught up into an intellectual treadmill and the liberty of their thought restrained. If this should be the result of organization, it has failed, but there is no thought to do this and, if it does happen, it means that organization has not fulfilled its useful purpose and should be resurveyed. Originality of thought and the flair for discovery will help the organization, for its purpose is to discover new things and any sensible director wants his group to succeed.

However, it is no use for anyone to protest against organization in research. It is inevitable and bound to come. The reason is the enlarged scale of operations which has occurred in almost every phase of human activity throughout the civilized world and research, even if it may lag in this regard, is bound to follow. The complexity of the implements for the attack of unknown problems, the great accumulation of recorded facts and the intricacy and vastness of the new discoveries of science all combine to make organization a natural result and are really bound up in the world-wide tendency toward greater scale of operations.

CURRENT TOPICS.

New Color Computing Device Developed by General Aniline.—How many colors are there? I. H. Godlove, Color Editor of Webster's New International Dictionary, says the eye can see about 10,000,000, but two scientists have now come up with an automatic machine so precise it can distinguish more than 100,000,000.

The new device, known as the General Aniline-Librascope Tristimulus Integrator, figures out the answer to a series of computations involving integral calculus before a man attempting the same job by hand can sharpen his pencil.

According to H. R. Davidson, the General Aniline & Film Corporation research physicist who invented it, and L. W. Imm of Librascope, Inc., Burbank, California, who engineered it, the device, which integrates continuously over all portions of the visible spectrum, will tell immediately whether a given color will match another color and, if not, will describe the difference between them. Without the integrator an answer to this question may take hours to get, and even then be less accurate.

Although the eye can tell whether two colors are the same, no one can describe color differences in words which mean the same thing to everybody. Color scientists, however, have developed an internationally accepted mathematical procedure for obtaining numbers which unambiguously specify any color.

In order to understand this method and the operation of the new computer, it is necessary to know that color as we see it is composed of three parts: First the light, which is energy radiating from the sun or a lamp, secondly the dyed, painted or naturally colored material under observation which reflects or transmits varying percentages of light of different wavelengths, and finally the eye itself. Internationally accepted data on the light and the eye are available, and reflectance or transmittance may be measured on an instrument known as a spectrophotometer. These three factors must be combined mathematically, but even a color blind person can make the necessary calculations and evaluate the color of any material.

Until the invention of the Tristimulus Integrator, this procedure required multiplication of the three values at scores of wavelengths and addition of the products. The integrator, an electronically controlled ball and disc mechanism which is connected directly to the spectrophotometer gives the correct result the instant the spectrophotometer has "looked" at the color. Together, the two instruments—the recording spectrophotometer and the Tristimulus Integrator—not only measure and analyze color in $2\frac{1}{2}$ minutes, but yield a numerical specification of what we see with hitherto unobtainable accuracy.

Colored Film for Ordinary Cameras.—A new color film with a speed rating which makes it possible for use in ordinary low-priced cameras has been announced by Ansco.

The film, called Plenacolor, is part of the Ansco Color negative process which provides for the making of paper prints in full color.

Allan Williford, Vice President of General Aniline & Film Corporation in charge of the Ansco Division, said that the initial release of the new Ansco product was limited to New York City and the metropolitan area, and Binghamton, New York, the home of Ansco.

The film will be made available in other parts of the country as rapidly as manufacturing and processing facilities can be established. Ansco developed the process during the war years, but deferred its release until all technical problems relative to its manufacture and processing were eliminated.

Plenacolor Film produces a complementary color negative from which full color prints can be made on a special double-weight paper. This provides the users with full color prints on paper which may be mounted in snapshot albums or framed. There is no limit to the number of prints which can be made from each negative.

Available in 120 and 620 six-exposure roll film sizes, Plenacolor may be exposed in any cameras using these sizes. Easy-to-understand instructions are packaged with the film. Plenacolor Film in 120 and 620 sizes will retail for $1.91 which includes the Federal excise tax and the processing of the negatives. Plenacolor prints will retail at 36¢ each.

Processing and printing as well as the sale of the new Ansco film will be handled only through Ansco dealers and the work will be done by the new Ansco Color laboratories in New York City, according to Mr. Williford, although the film, like all other Ansco films, will be made in Binghamton.

Plenacolor Film is guaranteed against manufacturing defects to the extent of replacement.

New Method of Connecting Tubes Increases Power of Television Stations in Ultra-High Frequency Bands.—A new method of combining transmitting tubes in groups or "clusters," which materially increases the power of television stations operating on ultra-high frequency (300 to 3000 megacycles), was revealed recently by G. H. Brown, W. C. Morrison, W. L. Behrend and J. G. Reddick of RCA Laboratories. The new method makes it possible to handle the normal band of frequencies involved in television transmission with greater signal strength than has heretofore been attained.

In the RCA method, two transmitter tubes—or two complete transmitters—are teamed through a special network called a duplexer, which permits the combined outputs of the tubes to be fed into the same antenna, thereby doubling the effective power output without narrowing the width of the frequency band transmitted. Since the output of the duplexer with the combined power of two tubes acts as a single unit, it is possible to combine two or more duplexers to multiply the output proportionately. This process can be continued to any extent desired.

It was stated in the paper that RCA has built a developmental television transmitter utilizing four output stages combined with three duplexers. With the four stages operating at a carrier frequency of 850 megacycles, the final output of the transmitter is four times the power obtained from a single stage.

It was also pointed out that the system makes it possible to remove any one of the transmitters in the cluster without interrupting the signal on the air, although the power radiated from the antenna will be decreased in proportion.

The system, it was emphasized, is not advocated as a means of obtaining high power from many *small* tubes. It is expected to be useful, however, when existing tubes have reached their maximum ability to handle power. When that point is reached, the RCA method of duplexing offers one more means of increasing the useful output of the television station.

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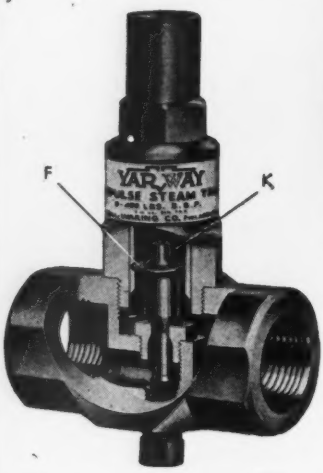

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All persons interested in the purposes and activities of the Institute and willing to further them, may become members when elected by the Board of Managers or in a manner prescribed by the Board. The following classes of membership are provided for in the By-Laws: Student, Associate, Active, Sustaining, Honorary.

Sustaining Members belong to the highest class of membership in the Institute and are entitled to all privileges of membership including Family Privileges. They are included among the Friends of Franklin, a group of public spirited citizens who contribute to the support of the Institute and in other ways call the attention of present-day Americans to the wisdom of Benjamin Franklin.

Sustaining Membership.....(annually) $50.00 or over

Active Members have the full use of the Library with the privilege of borrowing books. They are entitled to vote and to hold office. Subscription to the *Journal of The Franklin Institute* is included in their dues and they are sent each month a copy of *The Institute News* which contains a program of events and other items of interest. Their membership cards also entitle them to admission free of charge to the Museum, the Planetarium and the Museum demonstrations and lectures. Active Members who reside permanently at a distance of 50 miles or more from Philadelphia are permitted to pay annual dues of $7.50.

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Family Privileges may be obtained by Associate or Active Members on payment of $5.00 annually in addition to their regular dues. This entitles them to receive, for each individual in their family and resident with them, a card entitling the holder to unlimited free admission to the Museum and Planetarium.

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Student Membership.....(annually) $2.00
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Membership for Life may be obtained in the Associate and Active Classes on payment of $100 and $300 respectively. For those who reside permanently at a distance of fifty miles or more the fee for Active Membership for Life is $100.

The annual fees for membership are due and payable on the first day of the month of the date of election, or as determined by the Board of Managers. Any member whose dues are more than two months in arrears shall have all the privileges of membership suspended until such time as all arrears are paid. Should the dues not be paid when they become six months in arrears the said member shall forfeit his membership.

Firms, Corporations, Associations or **Individuals** may nominate and subscribe for the membership dues of groups of members of any class or classes, at the annual dues provided for, subject to the approval of the Board as to any particular nominee. If the dues of these nominees amount to $100 or more in the aggregate, the firm, corporation, association or individual shall be known as an Affiliate of the Institute.

Resignations of memberships shall be made to the Board of Managers in writing, but need not be accepted until all dues and arrears up to the date of resignation have been paid.

For further information and membership application blanks address the Secretary, The Franklin Institute, Benjamin Franklin Parkway at 20th Street, Philadelphia 3, Pa.

AWARDS BY THE INSTITUTE

The Franklin Medal (1914—Gold Medal).—This medal is awarded annually from the Franklin Medal Fund, founded January 1, 1914, by Samuel Insull, Esq., to those workers in physical science or technology, without regard to country, whose efforts, in the opinion of the Institute, acting through its Committee on Science and the Arts, have done most to advance a knowledge of physical science or its applications.

The Elliott Cresson Medal (1848—Gold Medal).—This medal is awarded for discovery or original research, adding to the sum of human knowledge, irrespective of commercial value; leading and practical utilizations of discovery; and invention, methods or products embodying substantial elements of leadership in their respective classes, or unusual skill or perfection in workmanship.

The Howard N. Potts Medal (1906—Gold Medal).—This medal is awarded for distinguished work in science or the arts; important development of previous basic discoveries; inventions or products of superior excellence or utilizing important principles.

The John Price Wetherill Medal (1925—Silver Medal).—This medal is awarded for discovery or invention in the physical sciences or for new and important combinations of principles or methods already known.

The Edward Longstreth Medal (1890—Silver Medal).—This medal is awarded for inventions of high order and for particularly meritorious improvements and developments in machines and mechanical processes. In the event of an accumulation of the fund for medals beyond the sum of one hundred dollars, it is competent for the Committee on Science and the Arts to offer from such surplus a money premium for some special work on any mechanical or scientific subject that is considered of sufficient importance.

The Louis E. Levy Medal (1923—Gold Medal).—This medal is awarded to the author of a paper of especial merit, published in the JOURNAL OF THE FRANKLIN INSTITUTE, preference being given to one describing the author's experimental and theoretical researches in a subject of fundamental importance.

The George R. Henderson Medal (1924—Gold Medal).—This medal is awarded for meritorious inventions or discoveries in the field of Railway Engineering.

The Walton Clark Medal (1926—Gold Medal).—This medal is awarded to the "author of the most notable advance in knowledge or improvement in apparatus, or in method concerning the science or the art of gas manufacture or distribution or utilization in the production of illumination, or of heat, or of power."

The Frank P. Brown Medal (1938—Silver Medal).—This medal is awarded to inventors for discoveries and inventions involving meritorious improvements in the building and allied industries.

The Newcomen Medal (1943—Gold Medal).—This medal is awarded, not oftener than once in three years, for achievement in the field of Steam.

The Francis J. Clamer Medal (1943—Silver Medal).—This medal is awarded at least once in five years for meritorious achievement in the field of Metallurgy.

The Stuart Ballantine Medal (1946—Gold Medal).—This medal is to be awarded in recognition of outstanding achievement in the fields of Communication and Reconnaissance which employ electromagnetic radiation.

The William M. Vermilye Medal (1937—Bronze Medal).—This medal is awarded biennially in recognition of outstanding contribution in the field of Industrial Management.

The Certificate of Merit (1882).—A Certificate of Merit is awarded to persons adjudged worthy thereof for meritorious inventions, discoveries or improvements in physical processes or devices.

The Boyden Premium.—Uriah A. Boyden, Esq., of Boston, Mass., has deposited with The Franklin Institute the sum of one thousand dollars, to be awarded as premium to "any resident of North America who shall determine by experiment whether all rays of light and other physical rays are or are not transmitted with the same velocity."

For further information relating to these awards apply to The Executive Director.

(Revised to April, 1948.)

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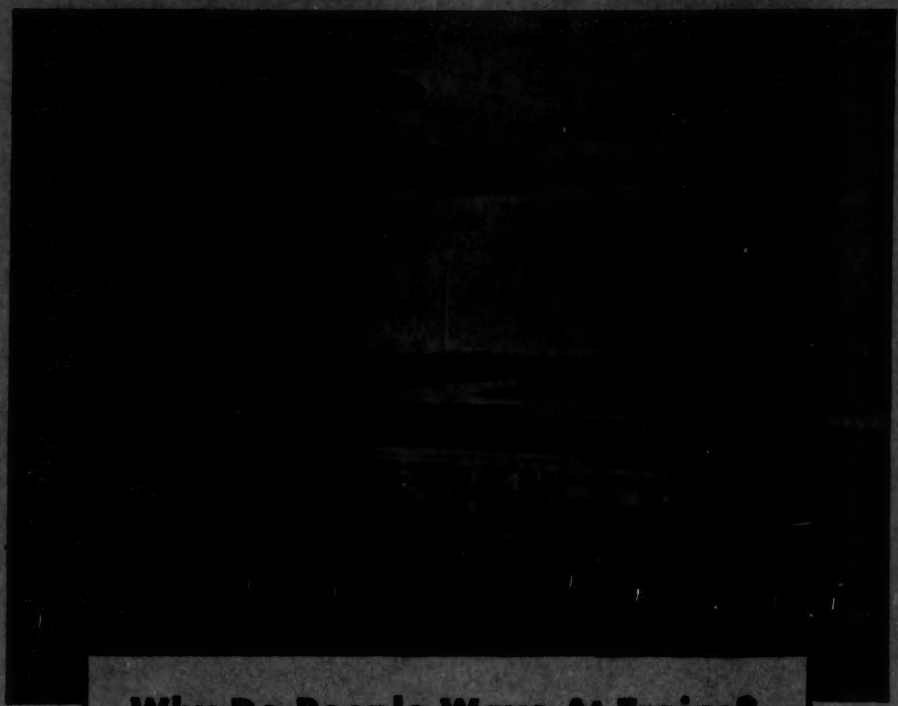

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